LOWER ARKANSAS BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody/Assessment Unit (AU): Lower Arkansas River – Derby to Ark City

Water Quality Impairment: Chloride

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin:	Ark River (Derby), Ark River (Oxford), Ark River (Ark City), South Fork Ninnescah River, Ninnescah River, Slate Creek, Unmonitored Basin
County:	Cowley, Sumner, Sedgwick, Kingman, Pratt, Kiowa
HUC 8:	11030013, 11030015, 11030016, 11060001
HUC 11 (HUC 14s):	11030013020(050) 11030013030(010, 030, 040, 050, 060, 070, 080, 090) 11030015010(010, 020, 030, 040, 050, 060, 070, 080, 090) 11030015030(010, 020, 030, 040, 050, 060) 11030016010(010, 020, 030, 040, 050) 11030016020(010, 020, 030) 11060001040(010)
Ecoregion:	Central Great Plains, Wellington-McPherson Lowland (27d) Flint Hills (28)
Drainage Area:	1,653 square miles

Main Stem Segments:	11030013	(AU Station 528):	Slate Cr (17)
		(AU Station 281):	Arkansas R (3-part)
		(AU Station 527):	Arkansas R (2-part, 3-part, 18)
		(AU Station 218):	Arkansas R (1, 2-part)
	11030015	(AU Station 036):	S.F. Ninnescah R (1,3,4,6)
	11030016	(AU Station 280):	Ninnescah R (1,3,8)
	11060001	(AU Station 218):	Arkansas R (14, 18)

Main Stem Segments with Tributaries by HUC 8 and Watershed/Station Number:

Table 1 (a-f)

a.

HUC8	**11030013**	
Watershed	**Slate Creek**	
Station		
528	Slate Cr (17) (partial)	Winser Cr (32)
		Antelope Cr (25)
		*Beaver Cr (29)**
		*Hargis Cr (24)**
		*Oak Cr (26)**
		*Spring Cr (27)**

* Not impaired

b.

HUC8	**11030013**	
Watershed	**Arkansas River (Derby)**	
Station		
281	Arkansas R (3 - part)	Spring Cr (37)

c.

HUC8	**11030013**	
Watershed	**Arkansas River (Oxford)**	
Station		
527	Arkansas R (2 -part)	Spring Cr (34)
		Lost Cr (23)
	Arkansas R (18)	
	Arkansas R (3 - part)	Bitter Cr (28)
		Dog Cr (531)

d.

HUC8	**11030013**	
Watershed	**Arkansas R (Arkansas City)**	
Station		
	Arkansas R (14): Downstream extension to HUC 11060001 from Sta. 218	
	Arkansas R (18): Downstream extension to HUC 11060001 from Sta. 218	
218	Arkansas R (1)	Negro Cr (20)
		Spring Cr (19)
		Spring Cr (21)
		Salt Cr (22)
		Beaver Cr (33)
	Arkansas R (2 - part)	

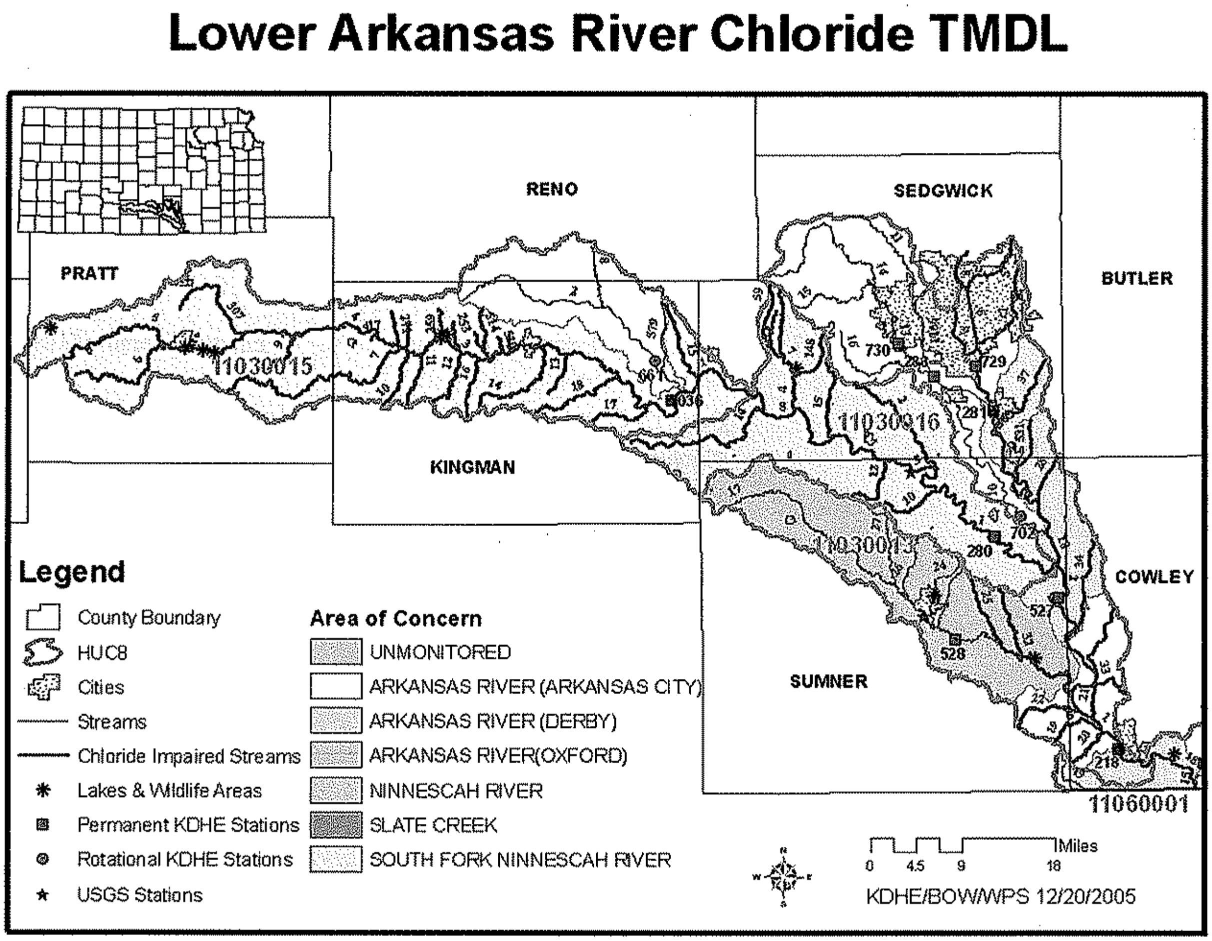
e.

HUC8	11030015		
Watershed	South Fk. Ninnescah R.		
Station			
36	S.F. Ninnescah R (1)	Nester Cr (15)	
	S.F. Ninnescah R (3)	Coon Cr (17)	
		Sand Cr (18)	
		Negro Cr (13)	
		Hunter Cr (14)	
		Unnamed Stream (249)	
		Unnamed Stream (520)	
		Unnamed Stream (514)	Unnamed Stream (518)
		Wild Run Cr (16)	
		Petyt Cr (12)	
		Unnamed Stream (253)	
		Unnamed Stream (259)	
		Unnamed Stream (261)	
		Pat Cr (11)	
		Mead Cr (10)	
		Unnamed Stream (270)	
		Painter Cr (7)	
		Unnamed Stream (271)	
	S.F. Ninnescah R (4)	Unnamed Stream (417)	
		Coon Cr (9)	
		Natrona Cr (307)	
		W. Br. S.F. Ninnescah R (5)	
	S.F. Ninnescah R (6)		

f.

HUC8	11030016			
Watershed	Ninnescah River			
Station				
280	Ninnescah R (1)	Elm Cr (10)		
		Spring Cr (2)		
	Ninnescah R (3)	Silver Cr (12)		
		Spring Cr (15)		
		Clearwater Cr (4)	Afton Cr (148)	
		Clearwater Cr (7)	Polecat Cr (59)	Clear Cr (161)
	Ninnescah R (8)	Sand Cr (14)		

Figure 1. Map of Study Area



Designated Uses: Domestic Water Supply

303(d) Listings: 2004 Lower Arkansas River Basin Streams
2002 Lower Arkansas River Basin Streams
1998 Table 1: Impaired streams impacted by non-point and point sources

Impaired Use: Domestic Water Supply

Water Quality Standard: Domestic Water Supply: 250 mg/L at any point of domestic water supply diversion (K.A.R.28-16-28e(c)(3)(A))

Aquatic Life Support [Acute criterion]: 860 mg/l for (KAR 28-16-28e(c)(2)(D)(ii))

In stream segments where background concentrations of naturally occurring substances, including chlorides and sulfates, exceed the domestic water supply criteria listed in table 1a in subsection (d), at ambient flow, due to intrusion of mineralized groundwater, the existing water quality shall be maintained, and the newly established numeric criteria for domestic water supply shall be the background concentration, as defined in K.A.R. 28-16-28b(e). Background concentrations shall be established using the methods outlined in the ''Kansas implementation procedures: surface water quality standards,'' as defined in K.A.R. 28-16-28b(gg), available upon request from the department. (K.A.R. 28-16-28e(c)(3)(B) and (b)(9))

In surface waters designated for the groundwater recharge use, water quality shall be such that, at a minimum, degradation of groundwater quality does not occur. Degradation shall include any statistically significant increase in the concentration of any chemical or radiological contaminant or infectious microorganism in groundwater resulting from surface water infiltration or injection. (KAR 28-16-28e(c)(5)).

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Use under 2004 303(d): Not Supporting Domestic Water Supply Use.

Stream Flow and Water Quality Monitoring Sites: USGS 07144550, 07145200, 07145500, 07145700, and 07146500; KDHE 281, 036, 280, 527, 528, and 218 (**Tables 2a, 2b, and 3**)

Period of Record used: 1970-2005 (**Tables 2a and 3**)

Long Term Flow Conditions: **Table 3**

Hydrology: The USGS flow data are summarized in Table 2. The Arkansas River from Derby to Arkansas City and the Ninnescah River are gaining streams. The chloride level in the water may prevent its use for irrigation, thus keeping consumption use along the rivers low. There are strong contributions from the ground water between Derby and Arkansas City as seen with the large increase in flows between Oxford and Arkansas City. The SF Ninnescah and Ninnescah Rivers lose some flows during the low flow conditions probably because of the regional ground water use by irrigation.

Current Conditions: The chloride data from the KDHE monitoring stations are summarized in **Tables 3a and 3b**. Sample data for each sampling site were categorized into three seasons: Spring (April-July), Summer-Fall (August-October), and Winter (November-March) (**Tables 2b and 4-9**). Among all the USGS chemistry monitoring stations only the Ark City site has a good collection of recent chloride data (since 1985). The chloride data collected by USGS at the Ark City site are comparable to the data collected by KDHE and are displayed in **Figure 8**.

Table 2a. Monitoring Sites Summary

KDHE Sites	Period of Record	Ave Cl (mg/L)	Max Cl (mg/L)	# of Samples	# > 250 mg/L	# > 860 mg/L	# > Back-ground	Nearby USGS Sites	Stream
SC281 (Ark R at Derby)	1985-2005	299	589	139	99	0	33	USGS 07144550 (Ark R at Derby)	Ark R.
SC 036 (SF Ninnescah R near Murdock)	1985-2005	235	399	138	52	0	39	USGS 07145200 (SF Ninnescah R near Murdock)	Ninnescah R. S Fk
SC 280 (Ninnescah R near Belle Plaine)	1985-2005	199	485	138	35	0	35	USGS 07145500 (Ninnescah R near Peck)	Ninnescah R.
SC527 (Ark R at Oxford)	1990-2005	227	412	91	43	0	32	USGS 07144550 (Ark R at Derby) USGS 07145500 (Ninnescah R near Peck)	Ark R.
SC 528 (Slate Creek near Wellington)	1990-2005	104	187	91	0	0	0	USGS 07145700 (Slate C at Wellington)	Slate Cr.
SC 218 (Ark R near Ark City)	1985-2005	283	619	140	93	0	42	USGS 07146500 (Ark R at Ark City)	Ark R.

Table 2b. Summary of Seasonal Chloride Data

	Spring Ave. (mg/L)			Summer/Fall Ave. (mg/L)			Winter Ave. (mg/L)		
KDHE Sites	Seasonal	Above Median Flow	At or Below Median Flow	Seasonal	Above Median Flow	At or Below Median Flow	Seasonal	Above Median Flow	At or Below Median Flow
SC281 (Ark R at Derby)	283	246	350	238	170	305	349	269	383
SC 036 (SF Ninnescah R near Murdock)	224	175	278	267	204	288	223	204	263
SC 280 (Ninnescah R near Belle Plaine)	186	141	263	234	133	287	189	149	234
SC527 (Ark R at Oxford)	205	171	280	226	156	284	246	211	265
SC 528 (Slate Creek near Wellington)	94	82	114	99	74	113	115	104	129
SC 218 (Ark R near Ark City)	248	193	359	288	211	380	309	262	343

Table 3: USGS Gage Flow Statistics

	Derby	Murdock	Peck	Oxford*	Wellington	Ark City
Time Period	1970-2005	1970-2005	1970-2005	1970-2005	1970-2005	1970-2005
Drainage Area (square miles)	44.9	649.3	408.7	109.2	289.8	99.8
Mean Flow (cfs)	1186	222	552	1988	77	2179
10% (cfs)	2530	337	1260	4388	81	4720
25% (cfs)	1070	210	540	1904	22	2140
Median (50%) (cfs)	517	147	233	950	8.9	1030
Upper Quartile (75%) (cfs)	300	108	133	529	3.7	555
Upper Decile (90%) (cfs)	197	76	82	329	1.1	378
95% (cfs)	169	64	60	275	0.44	330
99% (cfs)	122	43	38	183	0.14	208

* Determined from Derby and Ark City by regression

Because of the strong influx of chloride from the ground water, background concentrations were determined for all the monitoring stations (see Section 3 for more discussion). Load curves were established for the Domestic Water Supply criterion (250 mg/L) and the background levels by the following equation:

Load (tons/day) = flow (cfs) * Conc. (mg/L) * 5.4 (conversion factor) / 2000 (pounds/ton)

The domestic water supply criterion load curve represents the TMDL and is referred to as the TMDL load curve in this report, since any point along the curve denotes water quality for the standard at that flow (**Figures 2-8**). Historic excursions from the water quality standard are seen as plotted points above the TMDL load curve. Water quality standards are met for those points plotted on or below the TMDL load curve. The background load curves are displayed in **Figures 2-8** if they are higher than the domestic water supply criterion (250 mg/L). In general, lower flow rates imply higher chloride concentrations in the streams.

All of the other supporting graphs are in **Appendices A and** B.

Site 281 (Derby): Excursions in each of the three defined seasons are outlined in **Table 4**. Sixty-three percent of the Spring samples and 56% of the Summer-Fall samples are above the domestic water supply standard. Eighty-eight percent of the Winter samples are over the domestic supply criterion. Overall, 71% of the samples are above the domestic water supply standard. The high exceedance rate during the Winter season coincides with the low flow period of the year.

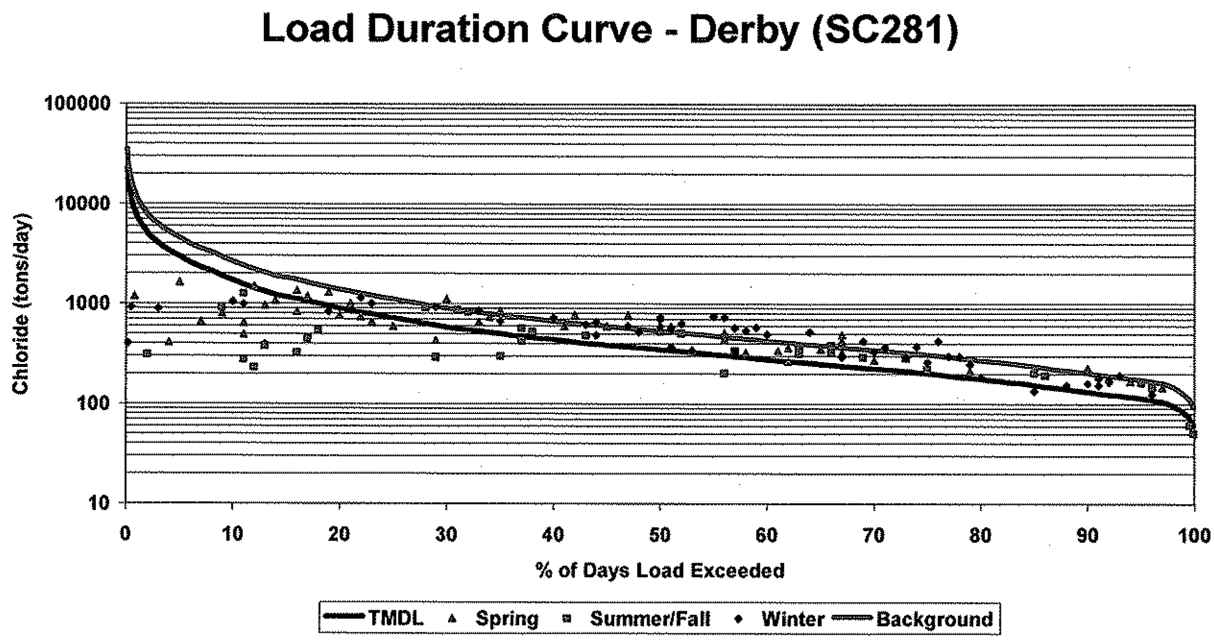
The TMDL load curve (**Figure 2**) indicates that the exceedances usually do not occur during high flow events (0-15% exceedance), which suggests that high flows and stormwater runoffs are not a concern for the chloride impairment. In fact, higher flows dilute the salt in the water and lower the chloride levels. At medium to low flow (>40% exceedance), the chloride standard was exceeded nearly at every point. At high to medium flow (15-40% exceedance), the standard was exceeded more than half of the times.

Since the streamflows in the Winter months are sustained mainly by the influx of the ground water, the background level at the station is determined from the Winter low flow samples (see Section 3). For the Derby station, the background level is set at 385 mg/L (see Section 3), a level much higher than the current domestic water supply standard of 250 mg/L. All the exceedances above the background concentration occurred at medium to low flows (30-90% exceedance). This implies that the area sources are probably the main contributor to all these exceedances **(Figure 2)**.

Table 4

NUMBER OF SAMPLES OVER CHLORIDE STANDARD OF 250 mg/L BY FLOW								
Station	**Season**	**0 to 10%**	**11 to 25%**	**26 to 50%**	**51 to 75%**	**76 to 90%**	**91 to 100%**	**Cum. Freq.**
Arkansas River at Derby (281)	Spring	0/5	4/15	11/12	11/12	2/2	2/2	30/48 = 63%
	Summer/Fall	0/2	0/7	5/8	10/11	2/2	2/4	19/34 = 56%
	Winter	0/4	2/4	12/12	21/21	8/9	7/7	50/57 = 88%

Figure 2. Load Curve – Derby



<u>**Site 036 (Murdock)**</u>**:** Excursions in each of the three defined seasons are outlined in **Table 5**. Thirty-three percent of the Spring samples and 60% of the Summer-Fall samples are over the domestic water supply standard. Twenty-eight percent of the Winter samples are over the domestic supply criterion. Overall, 38% of the samples are over the domestic water standard.

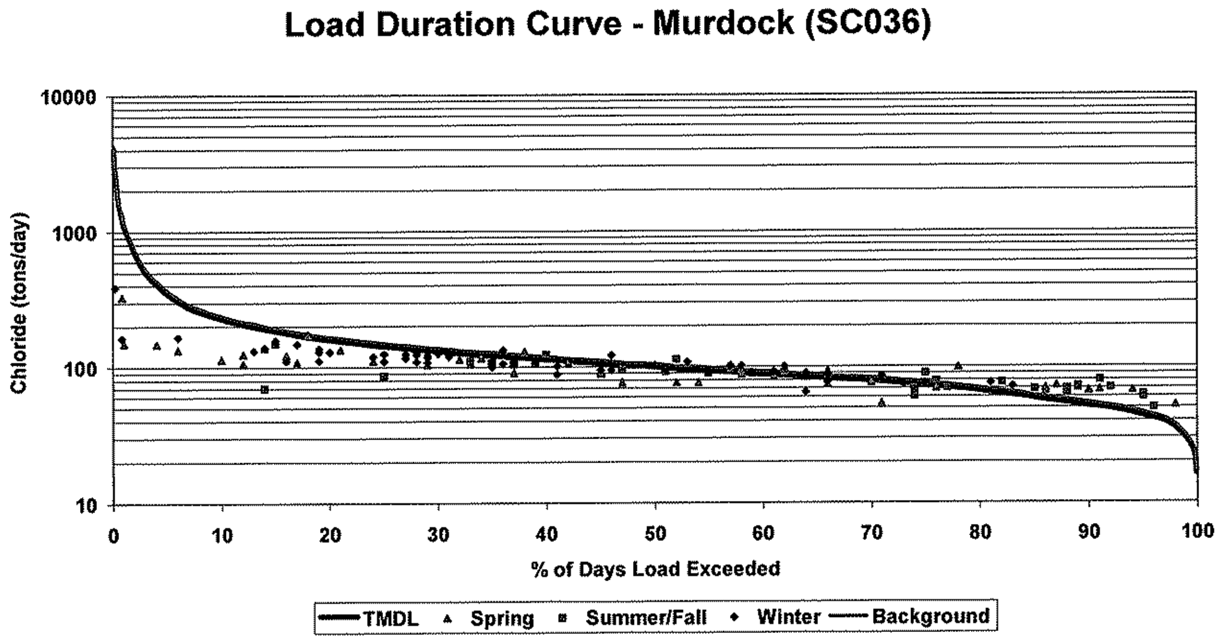
Most of the South Fork Ninnescah River sub-basin is located above the southeastern portion of the Great Bend Prairie Aquifer (**Appendix C** and **Figure 12**). The irrigation use of the ground water is heavy in the sub-basin area especially within the Pratt county, indicating the availability of fresh ground water in the area. The pumping of the ground water for irrigation use reduces the seepage of the fresh water to the streams. The chloride concentrations at or below median flows are higher during the Spring and Summer/Fall seasons since the irrigation use of the fresh ground water decreases the dilution of salt by the fresh water (**Figure 3**). The chloride concentrations are lower during the Winter season since irrigation is off and the freshwater resumes its entry into the streams.

Since the streamflows in the Winter months are sustained mainly by the influx of the ground water, the background level at the station is determined using the Winter samples (see Section 3). The background concentration is set at 265 mg/L. The exceedances over the standard occurred mainly during medium to low flow days (>50% exceedance) (**Figure 3**). All points at low flows (>80% exceedance) are over the standard, and most of the low flow exceedances (>85% exceedance) occurred in the Spring and Summer-Fall seasons. The main cause of these exceedances is probably not point source discharges but irrigation use of fresh ground water.

Table 5

NUMBER OF SAMPLES OVER CHLORIDE STANDARD OF 250 mg/L BY FLOW								
Station	**Season**	**0 to 10%**	**11 to 25%**	**26 to 50%**	**51 to 75%**	**76 to 90%**	**91 to 100%**	**Cum. Freq.**
SF Ninnescah R near Murdock (036)	Spring	0/5	1/8	1/11	3/11	7/8	3/3	15/46 = 33%
	Summer/Fall	0/0	0/3	1/6	7/12	7/8	6/6	21/35 = 60%
	Winter	0/3	0/12	3/24	11/16	2/2	0/0	16/57 = 28%

Figure 3. Load Curve – Murdock



Site 280 (Belle Plaine): Excursions in each of the three defined seasons are outlined in **Table 6**. Twenty-two percent of the Spring samples and 43% of the Summer-Fall samples are over the domestic water supply criterion. Eighteen percent of the Winter samples are over the domestic supply criterion. Overall, 25% of the samples are over the domestic water standard.

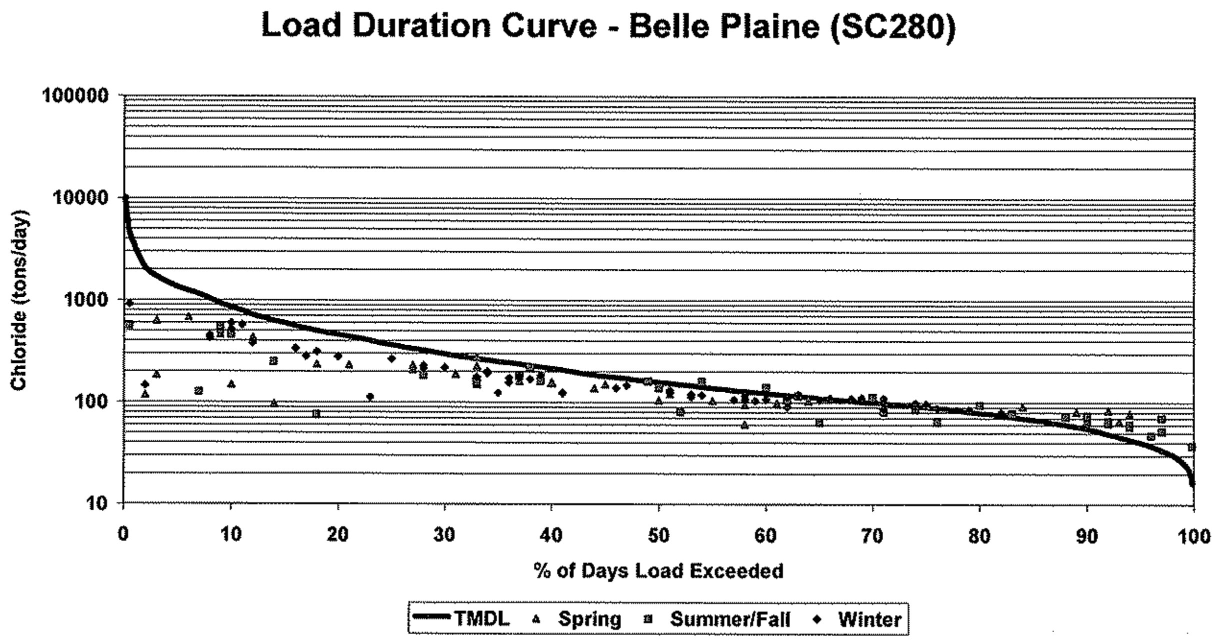
Parts of the Ninnescah River sub-basin are situated above a portion of the alluvial aquifer (**Appendix C**). The irrigation use of the ground water is heavy in those areas. The pumping of the ground water for irrigation use reduces the seepage of the fresh water to the streams. The chloride concentrations at or below median flows are higher during the Spring and Summer/Fall seasons since the irrigation use of the fresh ground water decreases the dilution of salt by the fresh water (**Figure 4**). The chloride concentrations are lower during the Winter season since irrigation is off and the freshwater resumes its entry into the streams.

Since the streamflows in the Winter months are sustained mainly by the influx of the ground water, the background level at the station is determined using the Winter samples (see **Section 3**). The background concentration is lower than the domestic water supply standard. The exceedances over the standard occurred mainly during medium to low flow events (>50% exceedance). All points at low flows (>80% exceedance) are over the standard, and most of the low flow exceedances (>85% exceedance) occurred in the Spring and Summer-Fall seasons. The main cause of these exceedances is probably not point source discharges but excessive use of the fresh ground water by irrigation.

Table 6

NUMBER OF SAMPLES OVER CHLORIDE STANDARD OF 250 mg/L BY FLOW								
Station	**Season**	**0 to 10%**	**11 to 25%**	**26 to 50%**	**51 to 75%**	**76 to 90%**	**91 to 100%**	**Cum. Freq.**
Ninnescah R near Belle Plaine (280)	Spring	0/8	0/4	1/18	2/9	4/4	3/3	10/46 = 22%
	Summer/Fall	0/4	0/2	0/7	3/9	4/5	8/8	15/35 = 43%
	Winter	0/6	0/8	0/16	8/24	2/3	0/0	10/57 = 18%

Figure 4. Load Curve – Belle Plaine/Peck



Site 527 (Oxford): Excursions in each of the three defined seasons are outlined in **Table 7**. Thirty-eight percent of the Spring samples and 55% of Summer-Fall samples are over the

domestic water supply criterion. Fifty-one percent of the Winter samples are over the domestic supply criterion. Overall, 47% of the samples are over the domestic water criteria.

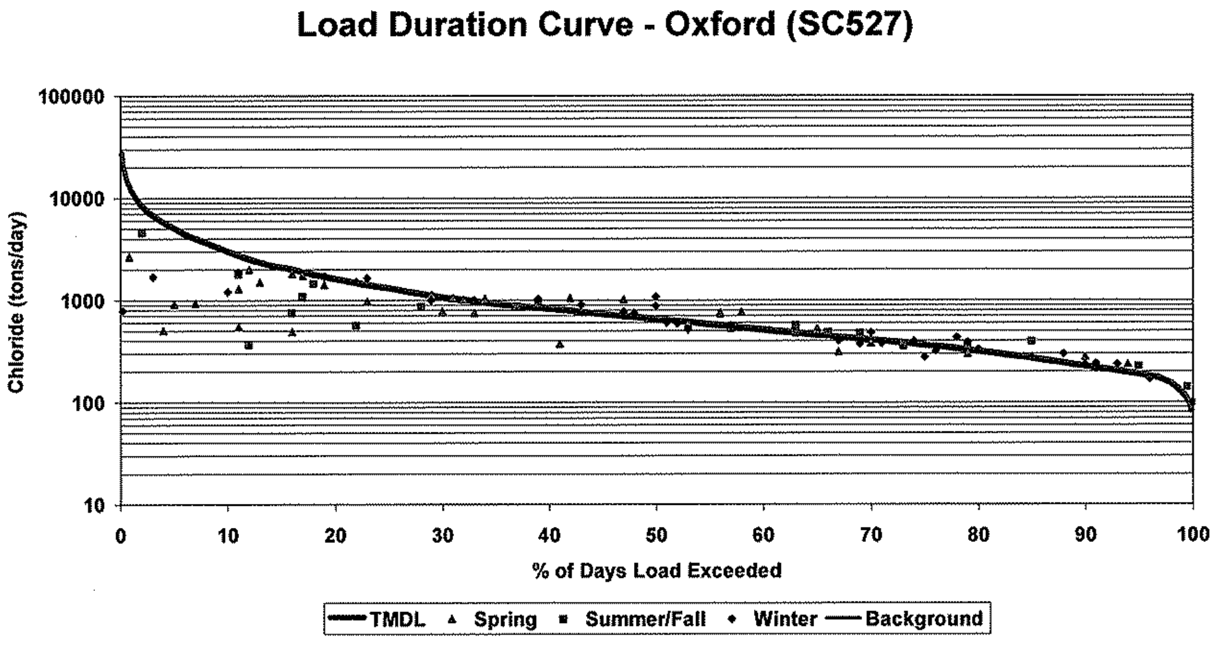
Oxford is downstream from Derby and Peck (Belle Plaine). Since there is no USGS gage station near Oxford, the Oxford flow data are derived by regression analysis using the Derby and Ark City flow data.

The background level at the station is determined using the Winter samples (see **Section 3**), since the streamflows in the Winter months are sustained mainly by the influx of the ground water. The background level is 265 mg/L, lower than the level at Derby. The lower background concentration indicates that there may be freshwater input between Peck and Oxford that allows the chloride to be more diluted than expected. The exceedances over the standard or the background level occurred mainly at medium to low flows (30-100% exceedance) (**Figure 5**). The exceedances at low flows (>90% exceedance) occurred mainly in the Spring and Summer-Fall seasons, probably due to the irrigation-caused low flows and higher loads from the upstream rivers (**Figure 5**).

Table 7

NUMBER OF SAMPLES OVER CHLORIDE STANDARD OF 250 mg/L BY FLOW								
Station	**Season**	**0 to 10%**	**11 to 25%**	**26 to 50%**	**51 to 75%**	**76 to 90%**	**91 to 100%**	**Cum. Freq.**
Arkansas River at Oxford (527)	Spring	0/4	0/9	6/9	4/7	1/2	1/1	12/32 = 38%
	Summer/Fall	0/1	0/6	2/3	5/7	2/2	3/3	12/22 = 55%
	Winter	0/3	2/4	7/8	3/11	5/7	2/4	19/37 = 51%

Figure 5. Load Curve – Oxford



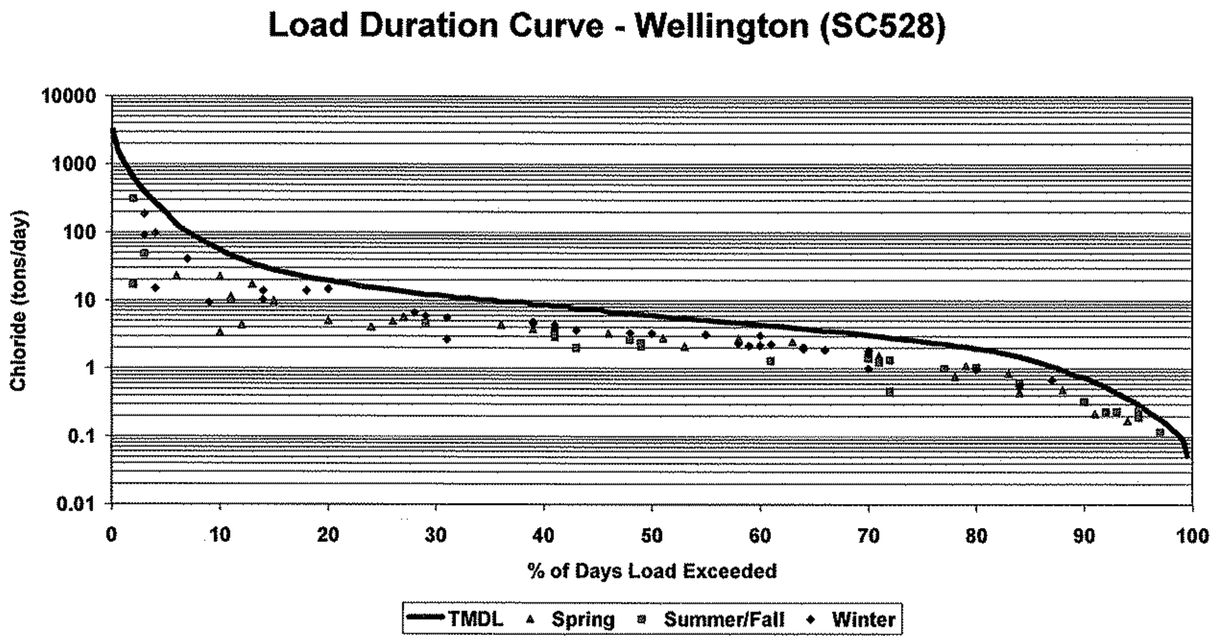
Site 528 (Wellington): No excursions were seen in each of the three defined seasons and are outlined in **Table 8.**

Streams above the Wellington station are not chloride impaired (**Figure 6**). Downstream from the monitoring station, the Slate Lake Wildlife Area is impaired for Chronic Aquatic Life Support due to very high levels of chloride. The average chloride concentration from 1997-1999 was 27,600 mg/L in the Slate Lake WA. The impairment is caused by the natural conditions. The Antelope Creek and the Winser Creek just above the Slate Lake WA are also chloride impaired due to the natural conditions, as per email communications from Dr. Don Whittemore of USGS. The high levels of chloride in these waters eventually flow into the Ark River and contribute to the increased chloride levels seen at the Ark City station.

Table 8

NUMBER OF SAMPLES OVER CHLORIDE STANDARD OF 250 mg/L BY FLOW								
Station	**Season**	**0 to 10%**	**11 to 25%**	**26 to 50%**	**51 to 75%**	**76 to 90%**	**91 to 100%**	**Cum. Freq.**
Slate Creek near Wellington (528)	Spring	0/3	0/8	0/9	0/5	0/5	0/2	0/32 = 0%
	Summer/Fall	0/3	0/0	0/5	0/5	0/4	0/5	0/22 = 0%
	Winter	0/6	0/4	0/12	0/12	0/3	0/0	0/37 = 0%

Figure 6. Load Curve – Wellington



Site 218 (Ark City): Excursions in each of the three defined seasons are outlined in **Table 9**. Forty-eight percent of the Spring samples and 69% of the Summer-Fall samples are over the domestic water supply criterion. Eighty-one percent of the Winter samples are over the domestic supply criterion. Overall, 66% of the samples are over the domestic water criteria. The high exceedance rate during the Winter season coincides with the low flow period of the year.

Data from the Ark City stations show a similar trend with the Derby station data (**Figure 7**). At high flow (<10% exceedance) no exceedances occurred. At medium to low flow (>40% exceedance) almost all points are above the standard. At high to medium flow (10-40% exceedance) nearly half of all points are above the standard.

Since the streamflows in the Winter months are sustained mainly by the influx of ground water, the background level at the station is determined using the Winter samples (see **Section 3**). The background concentration is set to be at 345 mg/L. Exceedances over the background level were observed at medium to low flow (>30% exceedance), indicating influences from area sources. The low flow exceedances (>90% exceedance) occurred mainly in the Spring and Summer-Fall seasons, probably due to the irrigation-caused low flows and higher loads from the upstream rivers.

Table 9

NUMBER OF SAMPLES OVER CHLORIDE STANDARD OF 250 mg/L BY FLOW								
Station	**Season**	**0 to 10%**	**11 to 25%**	**26 to 50%**	**51 to 75%**	**76 to 90%**	**91 to 100%**	**Cum. Freq.**
Arkansas River near Arkansas City (218)	Spring	0/5	2/16	8/13	8/9	4/4	1/1	23/48 = 48%
	Summer/Fall	0/1	1/7	7/11	7/7	3/3	6/6	24/35 = 69%
	Winter	0/5	0/3	15/17	18/18	11/12	2/2	46/57 = 81%

Figure 7. Load Curve – Ark City

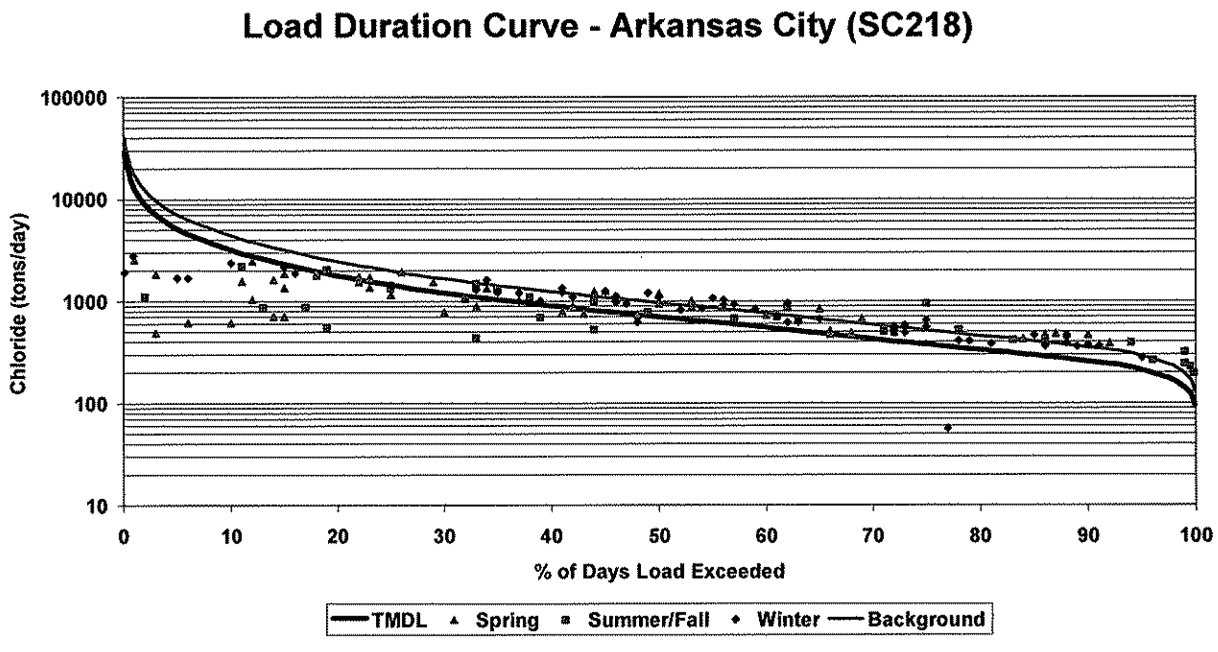


Figure 8. Load Curve – Ark City (USGS Data)

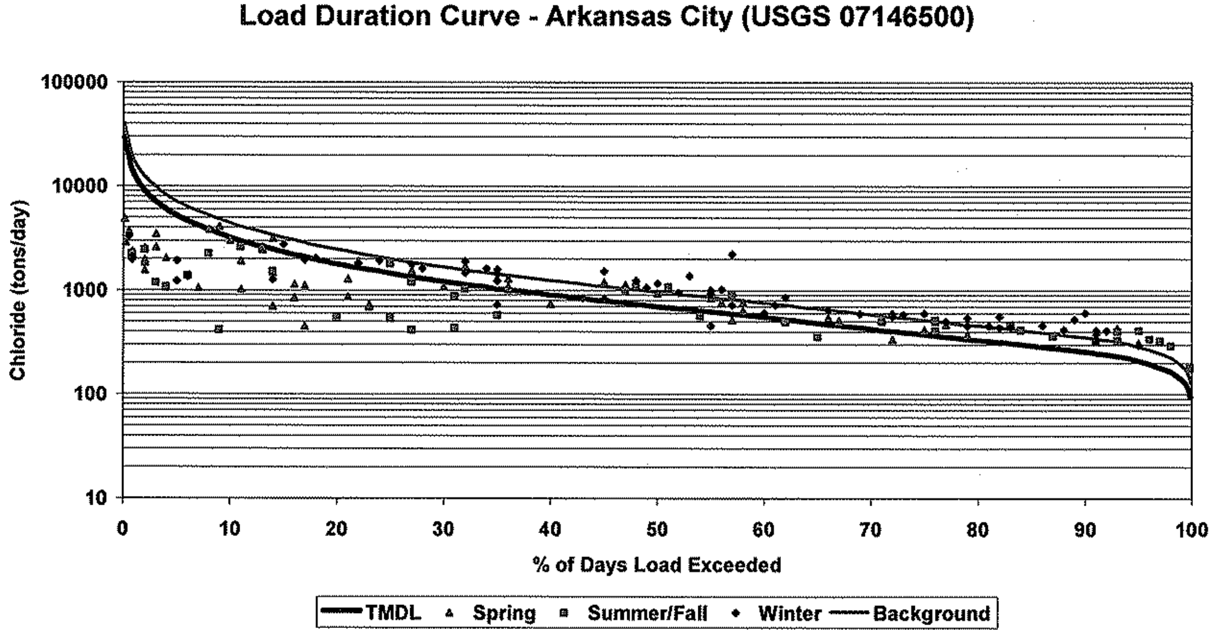


Figure 9. Derby and Oxford Chloride Data

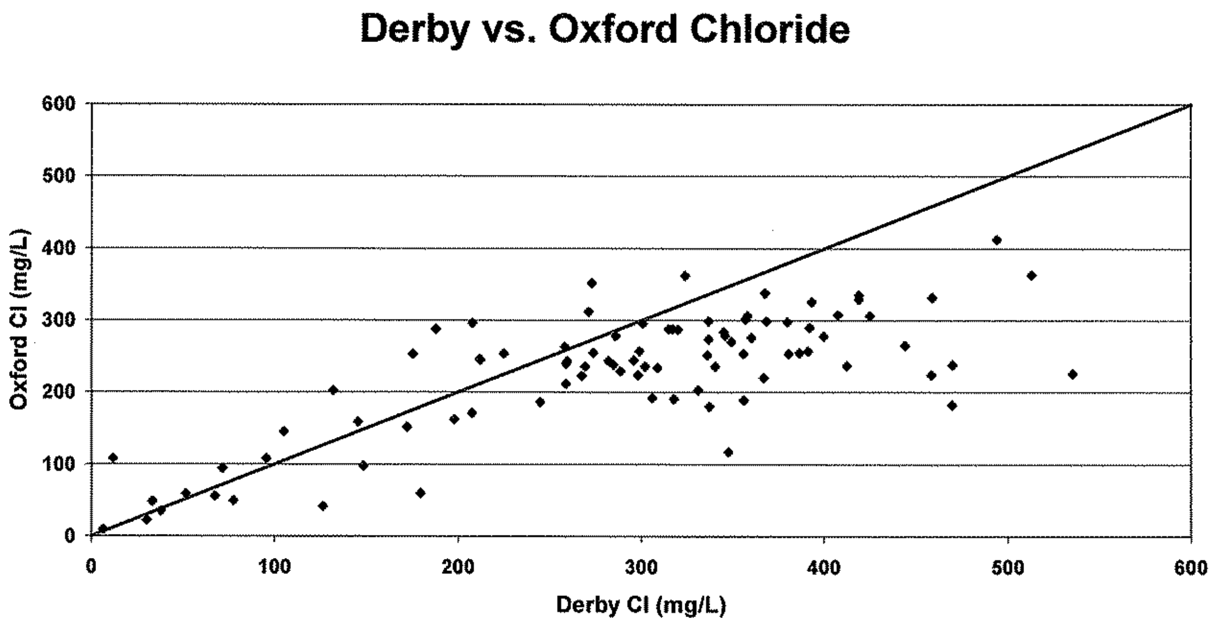


Figure 10. Murdock and Belle Plaine Chloride

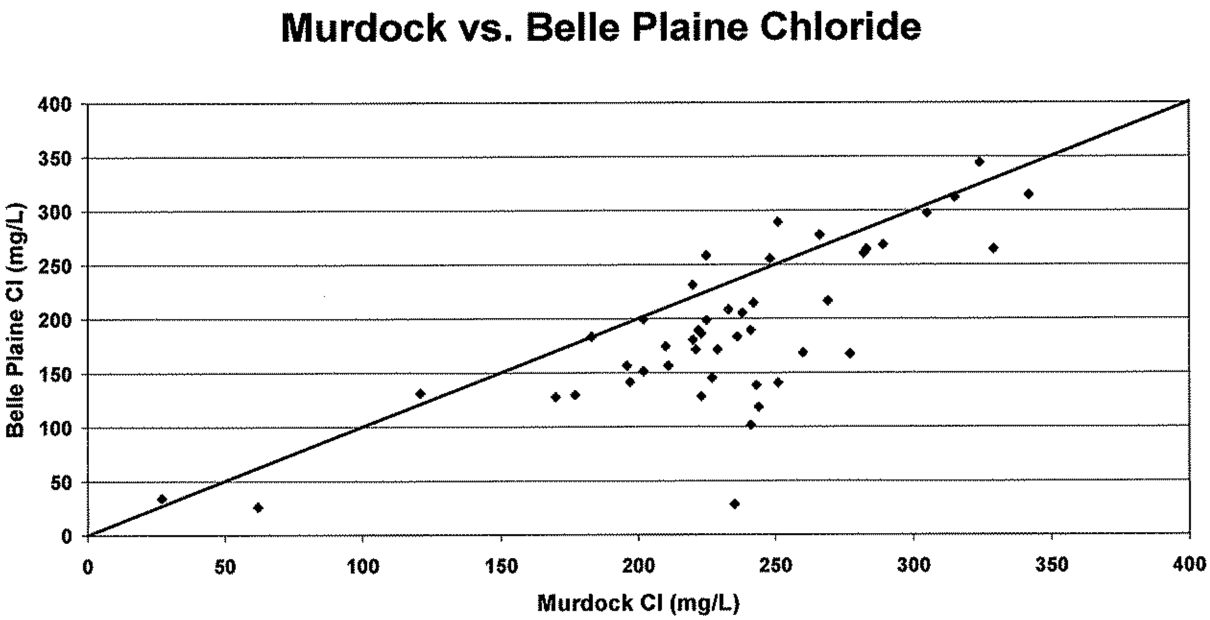


Figure 11. Belle Plaine and Oxford Chloride

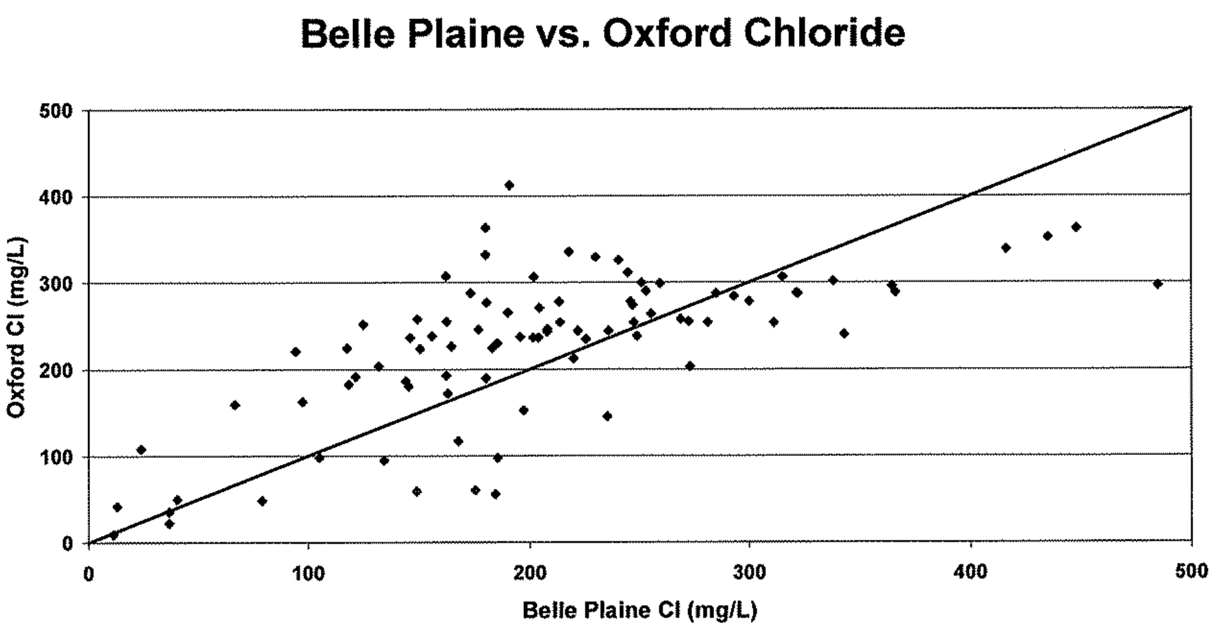


Figure 12. Wellington and Ark City Chloride

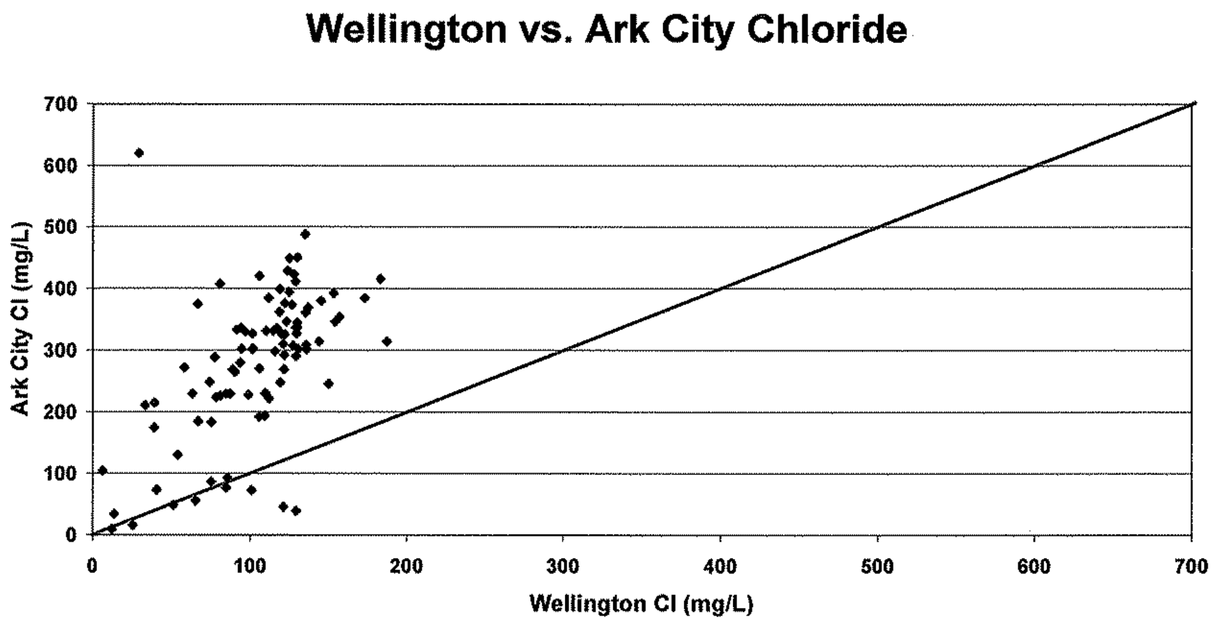
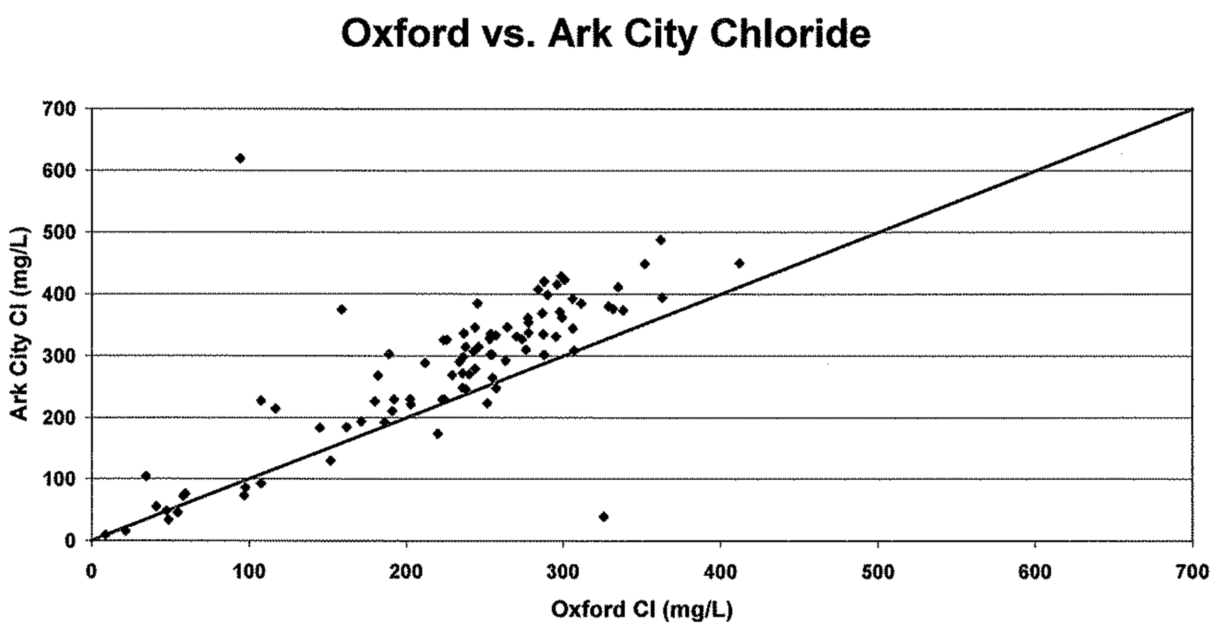


Figure 13. Oxford vs. Ark City Chloride



<u>Comparison of chloride levels between stations</u>: The comparisons of chloride concentrations between stations (**Figures 9-13**) clearly show a general pattern of dilution from Derby to Oxford and an increasing trend from Oxford to Ark City due to the natural contributions of the Slate Lake Wildlife Area.

The Ark River serves as the main dilution base and the Ninnescah River is the secondary dilution base. From Derby to Oxford (and probably to the confluence of the Slate Creek and the Ark River), the chloride concentrations gradually decline in the Ark River. At the confluence of the Slate Creek and the Ark River, the chloride levels in the Ark River jump higher due to the input from the Slate Creek Wildlife Area. Downstream from the confluence, the chloride levels probably decrease again gradually due to the influx of fresher water into the Ark River.

Desired Endpoints of Water Quality (Implied Load Capacity) at Sites 281, 036, 280, 527, 528, and 218, over 2006 – 2016

The ultimate endpoint for this TMDL will be to achieve the Kansas Water Quality Standards fully supporting Drinking Water Use. This TMDL will, however, be staged (**Table 10**). The current standard of 250 mg/L of chloride is used to establish the initial TMDL. Since the Standard is not achievable due to the relatively high natural contributions to the chloride load, an alternative endpoint is needed at sites 281, 036, 527, and 218. Kansas Water Quality Standards and their Implementation Procedures for Surface Water allow for a numerical criterion based on the natural background concentrations to be established, particularly from ambient samples taken at flows less than median flows. The Stage II end points are set at the background concentrations tentatively for sites 218, 036, 527, and 218. The specific stream criteria to supplant the general standard will be developed concurrent with Stage One of this TMDL.

Seasonal variation has been incorporated in this TMDL through the documentation of seasonal patterns of elevated chloride levels, especially during periods of low flows and extended drought. Achievement of the endpoints indicate loads are within the loading capacity of the stream, water quality standards are attained, and full support of the designated uses of the stream has been achieved.

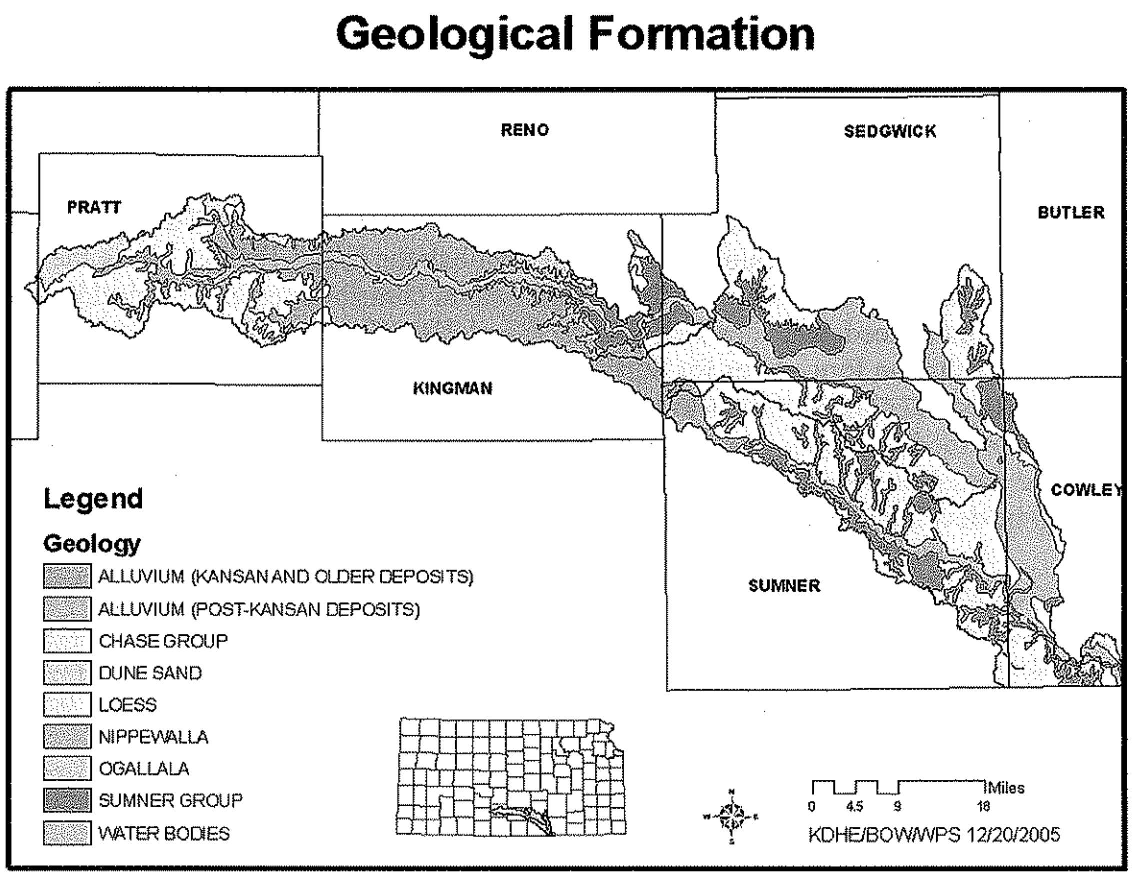
Table 10. Endpoints

Site	**Stage I End Point (mg/L)**	**Stage II End Point (mg/L)**
281 (Derby)	250	**385**
036 (Murdock)	250	**265**
280 (Peck/Belle Plaine)	250	250
527 (Oxford)	250	**265**
528 (Wellington)	250	250
218 (Ark City)	250	**345**

3. SOURCE INVENTORY AND ASSESSMENT

Chloride background assessment: Water quality is affected greatly by the influx of salty ground water from the underlying Permian rocks in all sub-basins (**Figure 14**). Since significant amounts of the water during the Winter low flow periods are from the ground water seepage, the background concentrations of chloride are determined by the average of the Winter samples whose flows are equal to or lower than the median flow (>=50%). **Table 10** lists the background concentrations at all the stations as the Stage II end points.

Figure 14. Geological Formation Map



NPDES:

There are seventeen permitted wastewater treatment facilities with design flows larger than 0.01 MGD discharging into the area (**Figure 15**). They are listed in **Table 11** by sub-basins. The low-discharging facilities (design flows<=0.01 MGD) have minimal impacts on the total loads in the sub-basins. Thus, the non-discharging and low-discharging facilities (design flows <= 0.01 MGD) are not considered in this TMDL. The two largest facilities are the wastewater treatment plants at Derby and Ark City. The total chloride loads from the 17 facilities are relatively small (1-2%) comparing to the total loads of the area.

Figure 15. Map of Wastewater Treatment Facilities

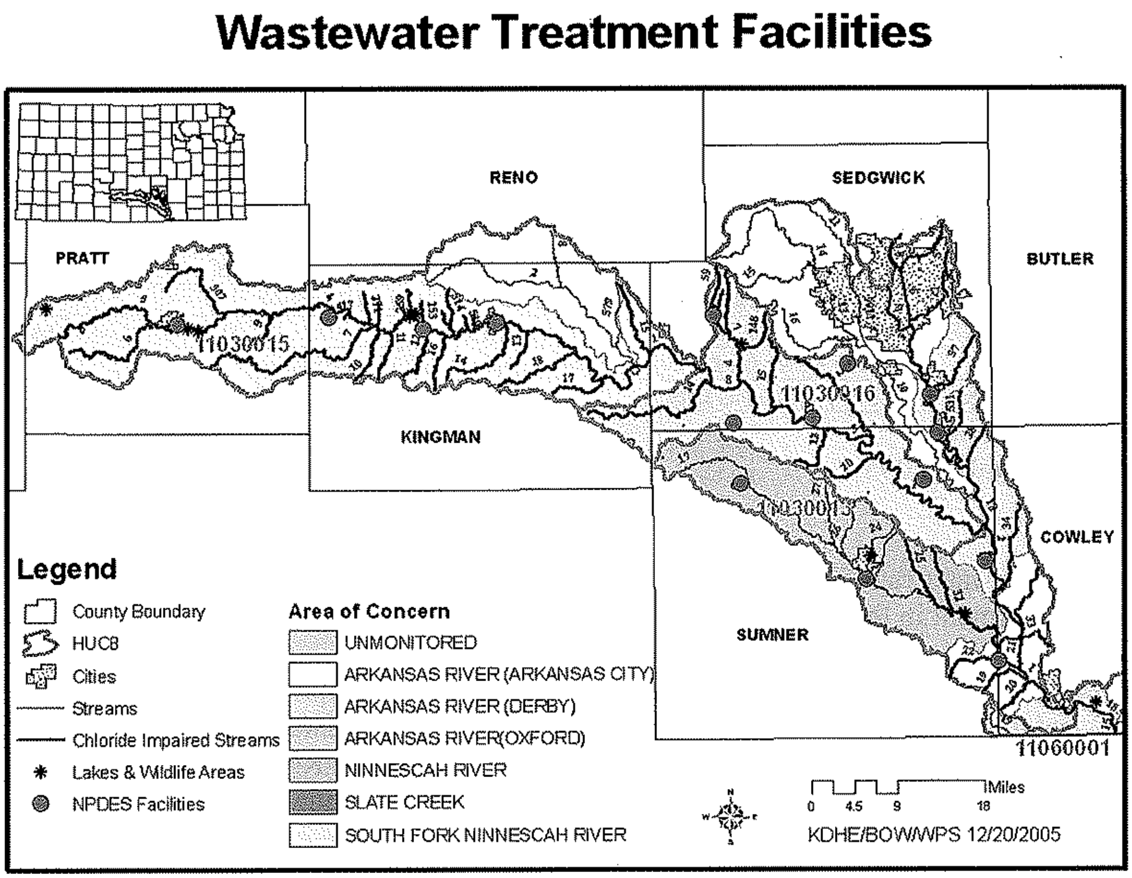


Table 11. Wastewater Treatment Facilities

KS #	NPDES #	Facility Name	Receiving Stream (main stem)	Design Flow (MGD)	Ave Cl (mg/L)
Ark River (Derby) Sub-basin (below Derby Station)					
M-AR29-OO02	KS0050377	Derby	Ark River	2.5	449
South Fork Ninnescah River Sub-basin (above Murdock Station)					
M-AR73-OO01	KS0049751	Pratt	SF Ninnescah River	1.1	na
M-AR27-OO01	KS0049743	Cunningham	SF Ninnescah River	0.087	na
I-AR96-PO01	KS0087823	KGS - Calista	SF Ninnescah River	0.0163	na
I-AR52-PO03	KS0117838	FABPRO	SF Ninnescah River	0.072	133
M-AR52-OO02	KS0095982	Kingman	SF Ninnescah River	0.75	na
Ninnescah River Sub-basin (above Peck Station)					
M-AR35-OO01	KS0116386	Garden Plain	Ninnescah River	0.132	119
M-AR90-OO01	KS0027880	Viola	Ninnescah River	0.0187	na
M-AR22-OO01	KS0022365	Clearwater	Ninnescah River	0.253	na
I-AR94-PO18	KS0080659	Air Products	Spring Creek	0.033	219
M-AR09-OO03	KS0094978	Belle Plaine	Ninnescah River	0.25	na
Ark River (Oxford) Sub-basin (above Oxford Station)					
M-AR64-OO01	KS0024635	Mulvane Municipal	Ark River	0.53	143
Ark River (Oxford) Sub-basin (below Oxford Station)					
M-AR68-OO01	KS0028011	Oxford	Ark River	0.181	na
Slate Creek Sub-basin (above Wellington Station)					
M-AR25-OO01	KS0030651	Conway Springs	Slate Creek	0.168	na
M-AR92-OO01	KS0020869	Wellington	Slate Creek	1.262	122**
Ark River (Ark City) Sub-basin (above Ark City Station)					
M-AR36-OO01	KS0116807	Geuda Springs	Salt Creek	0.0139	na
Ark River (Ark City) Sub-basin (below Ark City Station)					
M-AR06-IO01	KS0044831	Arkansas City	Ark River	2.1	153

na – data not available

** Since September 2005

Runoff: Stormwater runoff or high flow events are not a cause or contributing factor for the chloride impairment in the area (**Figures 2-8**).

Irrigation: The land use map (**Figure 16**) shows that the area comprises mainly croplands (59.5%) and grasslands (34.4%). According to the 2003 WIMAS data (**Figure 17**), irrigation occurred mainly in the South Fork Ninnescah River and Ninnescah River sub-basins (85.3% of the total water usage). Of the total usage, 97.4% came from the ground water (**Table 12**).

In the SF Ninnescah River sub-basin most of the ground water wells are located in the Pratt county and draw fresh water from the Great Band Prairie Aquifer (**Appendix C**). To the east of the Pratt Kingman county line, the number of wells decreases significantly and the wells tend to locate further away from the main stem. This probably reflects the SF Ninnescah River becomes salty due to the influx of Permian ground water with high chloride levels.

In the Ninnescah River sub-basin, most of the ground water wells are drawing water from the alluvial aquifer. The fresh ground water from the alluvial aquifer dilutes the water and lowers the chloride levels in the streams.

In both the SF Ninnescah River and Ninnescah sub-basins, irrigation use of the fresh ground water decreases the seepage of the fresh water to the streams and raises the chloride levels in the water during the low to median flow periods. The impact can also be observed in the downstream rivers. At the Oxford and Ark City stations, average chloride levels for the low to median flows are higher in the Spring and Summer/Fall seasons than the averages in the Winter season (**Table 2b**).

Table 12. Irrigation Use (2003)

Sub-basin	Monitoring Site	Site #	Surface W (acre-feet)	Ground W (acre-feet)	Total (acre-feet)
Ark R. - Derby	Derby	281	563	2775	3338
SF Ninnescah River	Murdock	036	643	58954	59597
Ninnescah River	Peck/B. P.	280	302	25438	25740
Ark R. - Oxford	Oxford	527	1142	2863	4002
Slate Creek	Wellington	528	0	2211	2211
Ark. R. – Ark City	Ark City	218	0	5118	5118
Total			**2650 (2.6%)**	**97359 (97.4%)**	**100009**

Brine from Oil and Gas: A few oil and gas fields are scattered in the area (**Figure 18**). Their effects to the watershed are probably localized to the production areas and not contributing to the chloride impairments.

Figure 16. Land Use Map

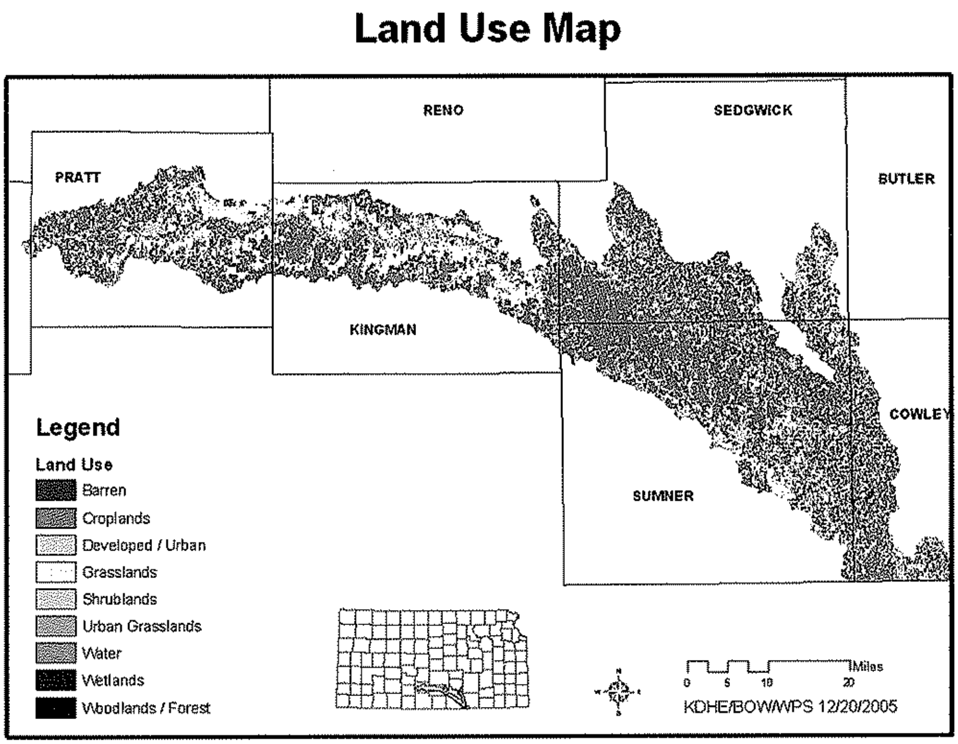


Figure 17. Irrigation Use – Points of Diversion

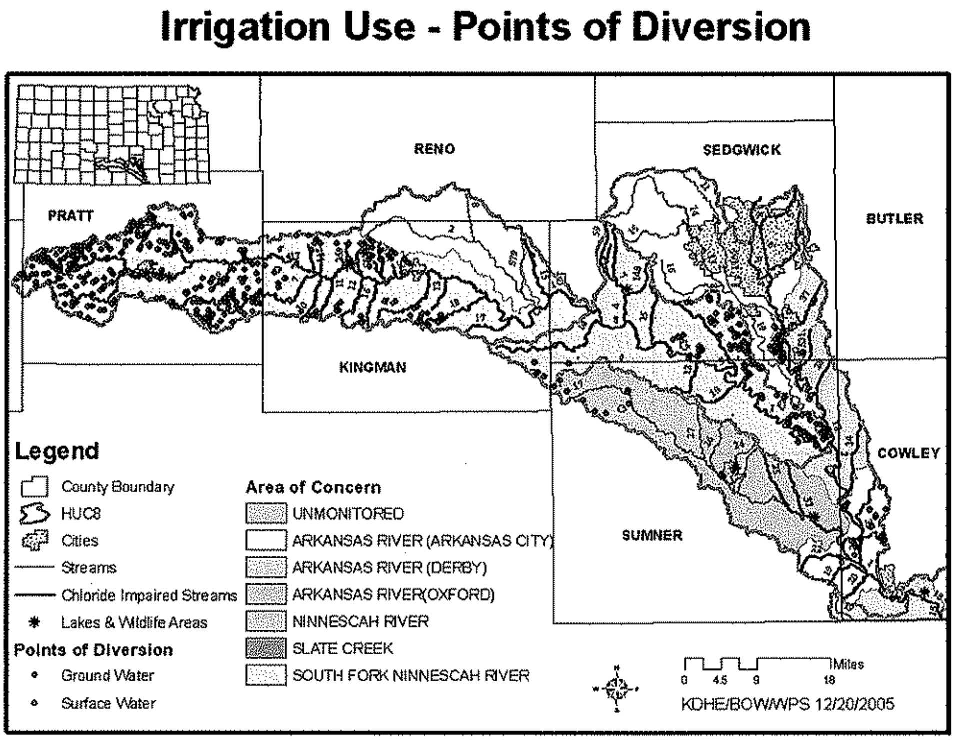
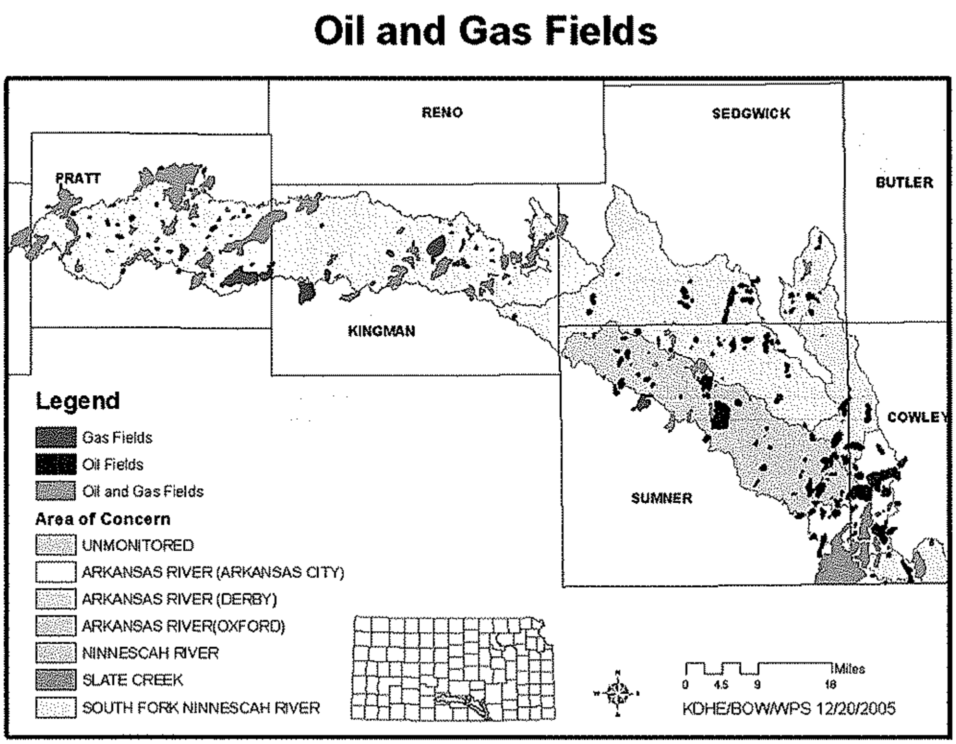


Figure 18. Oil and Gas Fields



4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

Point and Non-point Sources: Mass balance analysis was used to allocate the chloride loadings in the sub-basins. Data from Dec 91 (a known period of low flows) were used to calibrate the tributary flows, groundwater seepages, and point sources discharges. After the baseflow scenario was calibrated, five additional scenarios with different conditions were constructed. The conditions and loads of the six scenarios are listed in **Table 13**. The resulting chloride concentrations from the scenarios are listed in **Table 14**. Additionally, a scenario involving May 1992 low flow conditions was used to evaluate the impact of drought (**Tables 13-14**). The spreadsheets of the baseline, worst-case (GW project), and drought scenarios are provided in **Appendix D**.

Throughout the sub-basins, loads from the point sources have minimal impacts (<2%) on the total chloride loads. Even in the worst-case scenario with additions of the ground water remediation projects in all the sub-basins, the point sources only contribute about 5% of the total chloride loads at the baseflow.

Upstream chloride loads at Derby are a main contributor to the loads for the rest of the Arkansas River. At the baseflow, the loads above Derby account for approximately 47% of the loads at Arkansas City. At the median flow, upstream loads at Derby contribute about 59% of the chloride loads at Arkansas City. There is an increase in chloride concentration at Derby under median flow conditions over those seen at low flows. This indicates increasing loadings above Derby occur with higher flows, specifically higher flows from Maize. The impact of less water coming from Maize can be observed during the Winters of 90-91 and 91-92. The chloride levels at Derby, Oxford, and Ark city dropped significantly in the 91-92 Winter than the levels in the previous Winter, when the percentage of flow at Derby coming from Maize fell from 41% in the 90-91 Winter to 20% in the 91-92 Winter.

The loads from the Ninnescah River and SF Ninnescah River sub-basins are relatively constant from the baseflow to the median flow range. At the baseflow, the loads at Peck account for about 39% of the loads at Ark City. At the median flow, the loads at Peck contribute around 9% of the loads at Ark City. At low flows, there are chloride load losses in both the Ninnescah River and Ark River-Oxford sub-basins, probably due to irrigation.

The other main contributor is the natural background loadings through ground water seepage. One of the main sources of the natural contribution is the Slate Creek Wildlife Area located in the lower Slate Creek sub-basin. KDHE already established a chloride TMDL for the Slate Creek Wildlife Area. The loads in the SF Ninnescah River sub-basin also come mainly from the ground water seepage.

Drought may increase the chloride levels in the rivers by decreasing the fresh water input into the streams. The higher chloride loads and concentrations in the May 92 scenario are likely caused by a prolonged period of drought the region was experiencing.

Defined Margin of Safety: The Margin of Safety is implicitly set because the endpoints are established from the Winter data when man-made influences are minimal but apply to all streams and flow conditions. Furthermore, loadings from the point sources act as a dilution base for natural chloride contributions.

State Water Plan Implementation Priority: Because the chloride impairment is due to upstream loading and geologic sources, this TMDL will be a Low Priority for implementation.

Unified Watershed Assessment Priority Ranking: The watersheds lie within the Lower Arkansas Basin (HUC 8: part of 11030015, 11030016, part of 11030013, part of 11060001) with priority rankings of 15 for 11030015 and 6 for 11030013 (Priority for restoration work).

Priority HUC 11s and Stream Segments: Because of the natural geologic contribution of this impairment, no priority sub-watersheds or stream segments will be identified.

Table 13. Loads and Allocations (tons/day)

Allocations	**Base-flow (Dec 91)**	**Design Flow A**	**Design Flow B**	**No Point Source**	**50% (Jan 94)**	**GW Project**	**May 92**
Lower Ark River at Derby	**128.6**	**130.1**	**130.1**	**125.4**	**594.8**	**131.1**	**171.3**
Ark River Upstream	125.4	125.4	125.4	125.4	591.7	125.4	168.2
Wasteload	3.1	4.7	4.7	0	3.1	5.6	3.1
SF Ninnescah River at Murdock	**108.7**	**109.5**	**110.3**	**107.0**	**95.1**	**111.2**	**98.9**
Wasteload	1.7	2.5	3.3	0	1.7	4.2	1.7
Tributary and Alluvial Load	107.0	107.0	107.0	107.0	93.4	107.0	97.2
Ninnescah River at Peck	**94.1**	**95.2**	**96.2**	**91.9**	**106.3**	**99.1**	**90.0**
SF Ninnescah River	108.7	109.5	110.3	107.0	95.1	111.2	98.9
Wasteload	0.5	0.7	1.0	0	0.5	3.0	0.5
Tributary and Alluvial Load	-15.1	-15.1	-15.1	-15.1	-2.19	-15.1	-9.4
Lower Ark River at Oxford	**169.2**	**172.0**	**173.0**	**163.7**	**870.0**	**179.3**	**234.9**
Lower Ark River at Derby	128.6	130.1	130.1	125.4	594.8	131.1	171.3
Ninnescah River at Peck	94.1	95.2	96.2	91.9	106.3	99.1	90.0
Wasteload	0.2	0.3	0.3	0	0.2	2.7	0.2
Tributary and Alluvial	-53.6	-53.6	-53.6	-53.6	168.7	-53.6	-26.6
Upper Slate Creek at Wellington	**1.5**	**1.8**	**1.8**	**0.9**	**2.22**	**4.0**	**2.5**
Wasteload	0.6	0.9	0.9	0	0.6	3.1	0.6
Tributary and Alluvial Load	0.9	0.9	0.9	0.9	1.7	0.9	1.9
Lower Ark River at Ark City	**276.0**	**279.1**	**280.3**	**269.7**	**1015.7**	**291.0**	**382.9**
Lower Ark River at Oxford	169.2	172.0	173.0	163.7	870.0	179.3	234.9
Upper Slate Creek at Wellington	1.5	1.8	1.8	0.9	2.2	4.0	2.5
Lower Slate Creek	75.6	75.6	75.6	75.6	75.6	75.6	108
Wasteload	0.2	0.2	0.3	0	0.2	2.7	0.2
Tributary and Alluvial Load	29.5	29.5	29.5	29.5	67.8	29.5	37.4
Lower Ark River – Below SC218	**276.9**	**280.4**	**281.6**	**269.7**	**1016.6**	**291.9**	**383.8**
Lower Ark River at Ark City	276.0	279.1	280.3	269.7	1015.7	291.0	382.9
Wasteload	0.9	1.3	1.3	0	0.9	0.9	0.9

1. Baseflow: Dec 91 conditions, point sources at 2/3 of the design flow and 300 mg/L if no data are available
2. Design Flow A: Dec 91 conditions, point sources at the design flow and 300 mg/L if no data are available
3. Design Flow B: Dec 91 conditions, point sources at the design flow and 400 mg/L if no data are available
4. No Point Source: Dec 91 conditions, no discharges for point sources
5. 50%: 50 percentile conditions in Jan 1994, point sources at 2/3 of the design flow and 300 mg/L if no data are available
6. GW Project: Dec 91 conditions, hypothetical groundwater remediation projects added discharging 1 MGD at 600 mg/L to each sub-basin, point sources at 2/3 of the design flow and 300 mg/L if no data are available
7. May 92 Condition: Point sources at 2/3 of the design flow and 300 mg/L if no data are available

Table 14. Chloride Concentrations (mg/L)

Sub-basins	Stage II Back-ground Conc.	Base-flow (Dec 91)	Design Flow A	Design Flow B	No Point Source	50% (Jan 94)	GW Project	May 92
Lower Ark River at Derby	385	285	289	289	285	419	290	359
SF Ninnescah River at Murdock	265	259	260	262	259	243	263	359
Ninnescah River at Peck	250	253	253	256	252	217	261	315
Lower Ark River at Oxford	265	238	240	241	236	335	247	306
Upper Slate Creek at Wellington	250	117	121	125	105	129	237	153
Lower Ark River at Ark City	345	315	315	316	315	411	323	392

1. Baseflow: Dec 91 conditions, point sources at 2/3 of the design flow and 300 mg/L if no data are available
2. Design Flow A: Dec 91 conditions, point sources at the design flow and 300 mg/L if no data are available
3. Design Flow B: Dec 91 conditions, point sources at the design flow and 400 mg/L if no data are available
4. No Point Source: Dec 91 conditions, no discharges for point sources
5. 50%: 50 percentile conditions in Jan 1994, point sources at 2/3 of the design flow and 300 mg/L if no data are available
6. GW Project: Dec 91 conditions, hypothetical groundwater remediation projects added discharging 1 MGD at 600 mg/L to each sub-basin, point sources at 2/3 of the design flow and 300 mg/L if no data are available
7. May 92 Condition: Point sources at 2/3 of the design flow and 300 mg/L if no data are available

5. IMPLEMENTATION

Desired Implementation Activities

1. Monitor and limit any anthropogenic contributions of chloride loading to river.
2. Establish alternative background criterion.
3. Employ Best Management Practices to reduce the use of ground water for irrigation.

Implementation Programs Guidance

NPDES and State Permits - KDHE

a. NPDES and state permits for facilities in the watershed will be renewed after 2007 with chloride monitoring and any appropriate permit limits which protects the background concentrations and the domestic water supply criteria at any existing or emerging drinking water point of diversion on these streams as well as aquatic life and ground water recharge.

Non-Point Source Pollution Technical Assistance - KDHE

a. Evaluate any potential anthropogenic activities that might contribute chloride to the river as part of an overall Watershed Restoration and Protection Strategy.

Water Quality Standards and Assessment - KDHE

a. Establish background levels of chloride for the river.

Timeframe for Implementation: Development of a background level-based water quality standard should be accomplished with the water quality standards revision.

Targeted Participants: Primary participant for implementation will be KDHE.

Milestone for 2011: The year 2011 marks the midpoint of the ten-year implementation window for the watershed. At that point in time, sampled data from the watersheds should indicate no evidence of increasing chloride levels relative to the conditions seen in 1990-2005. Should the case of impairment remain, source assessment, allocation and implementation activities will ensue.

Delivery Agents: The primary delivery agent for program participation will be KDHE.

Reasonable Assurances:

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution.

1. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

2. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

3. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control nonpoint source pollution.

4. K.S.A. 82a-901, et seq. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

5. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan.*

6. The *Kansas Water Plan* and the Lower Arkansas Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

Funding: The State Water Plan Fund, annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the *Kansas Water Plan.* The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This watershed and its TMDL are a Low Priority consideration.

Effectiveness: Minimal control can be exerted on natural contributions to loading.

6. MONITORING

KDHE will continue to collect bimonthly samples at Stations 281, 036, 280, 527, 528, and 218, including chloride samples, in each of the three defined seasons over 2006-2011. Based on that sampling, the priority status will be evaluated in 2012 including application of numeric criterion based on background concentrations. Should impaired status remain, the desired endpoints under this TMDL will be refined and more intensive sampling will be needed under specified seasonal flow conditions after 2012.

Monitoring of chloride levels in effluent will be a condition of NPDES and state permits for facilities. This monitoring will continually assess the contributions of chloride in the wastewater effluent released to the stream.

7. FEEDBACK

Public Meetings: Public meetings to discuss TMDLs in the Lower Arkansas Basin were held on June 7, 2006 in Hutchinson. An active Internet Web site was established at http://www.kdhe.state.ks.us/tmdl/ to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Lower Arkansas Basin.

Public Hearing: Public Hearings on the TMDLs of the Lower Arkansas Basin were held on June 7, 2006 in Hutchinson. The public record was held open until June 20, 2006. No comments were received by KDHE.

Basin Advisory Committee: The Lower Arkansas Advisory Committee met to discuss the TMDLs in the basin on June 7, 2006.

Milestone Evaluation: In 2011, an evaluation will be made as to the degree of implementation that has occurred within the watershed and current condition of the Arkansas River and the Ninnescah River. Subsequent decisions will be made regarding the implementation approach and follow up of additional implementation in the watershed.

Consideration for 303(d) Delisting: The stream will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2006-2011. Therefore, the decision for delisting will come about in the preparation of the 2012 303(d) list. Should modifications be made to the applicable water quality criteria during the ten-year implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

Incorporation into Continuing Planning Process, Water Quality Management Plan and the Kansas Water Planning Process: Under the current version of the Continuing Planning Process, the next anticipated revision will come in 2006 which will emphasize implementation of TMDLs. At that time, incorporation of this TMDL will be made into both documents. Recommendations of this TMDL will be considered in Kansas Water Plan implementation decisions under the State Water Planning Process for Fiscal Years 2007-2011.

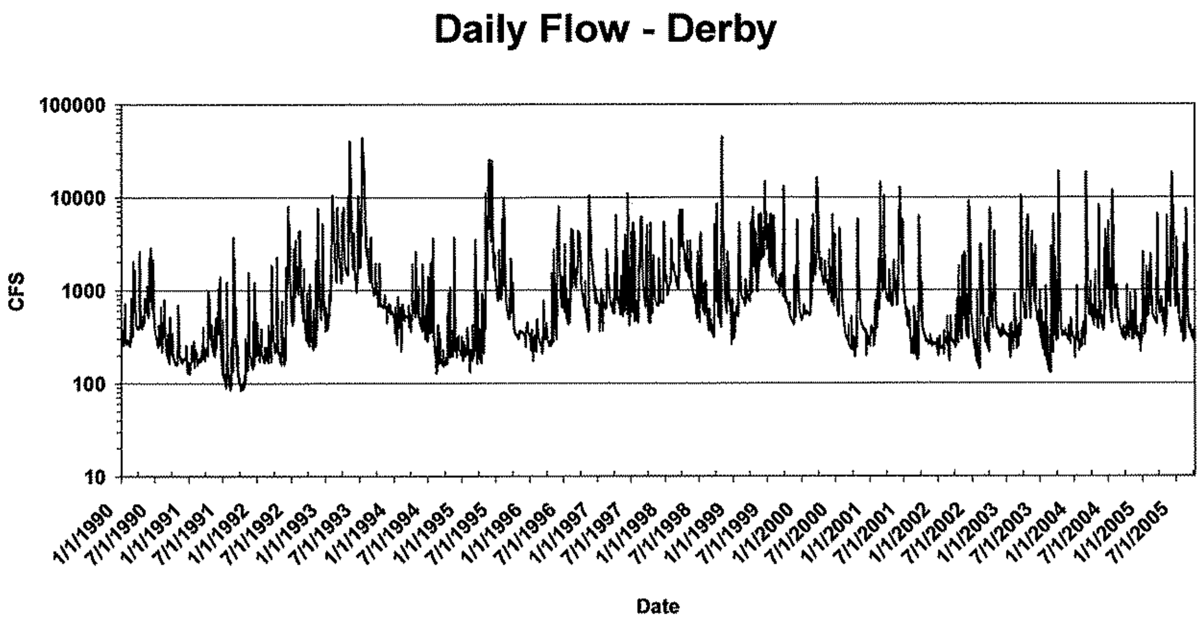
Revised 6/28/2006

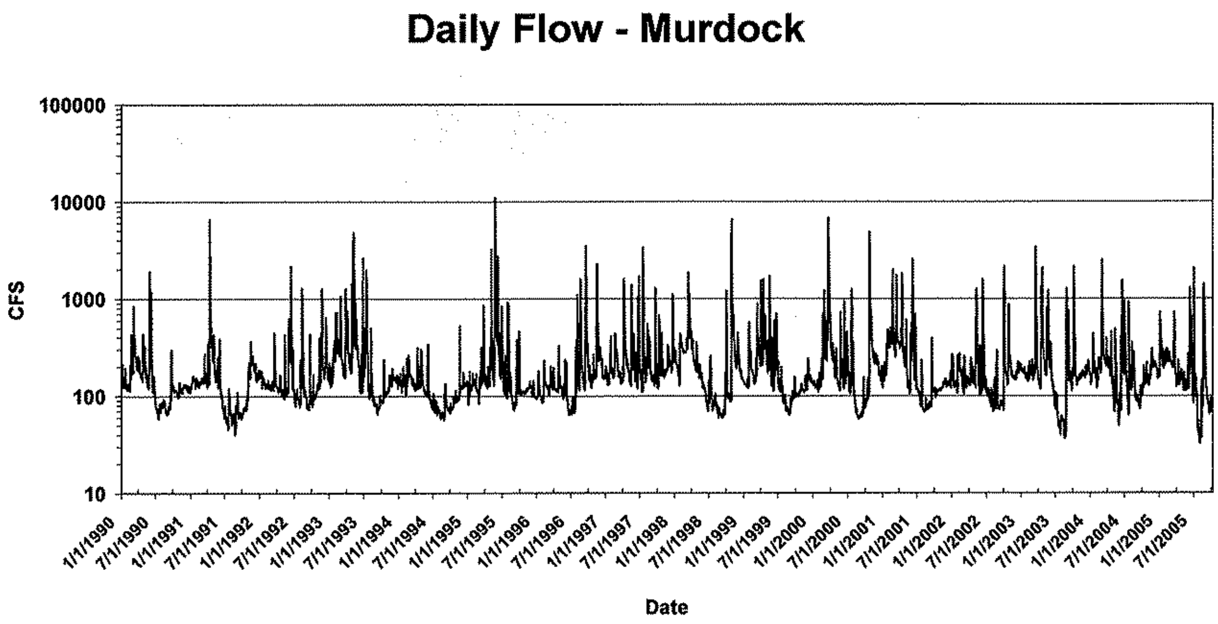
Bibliography

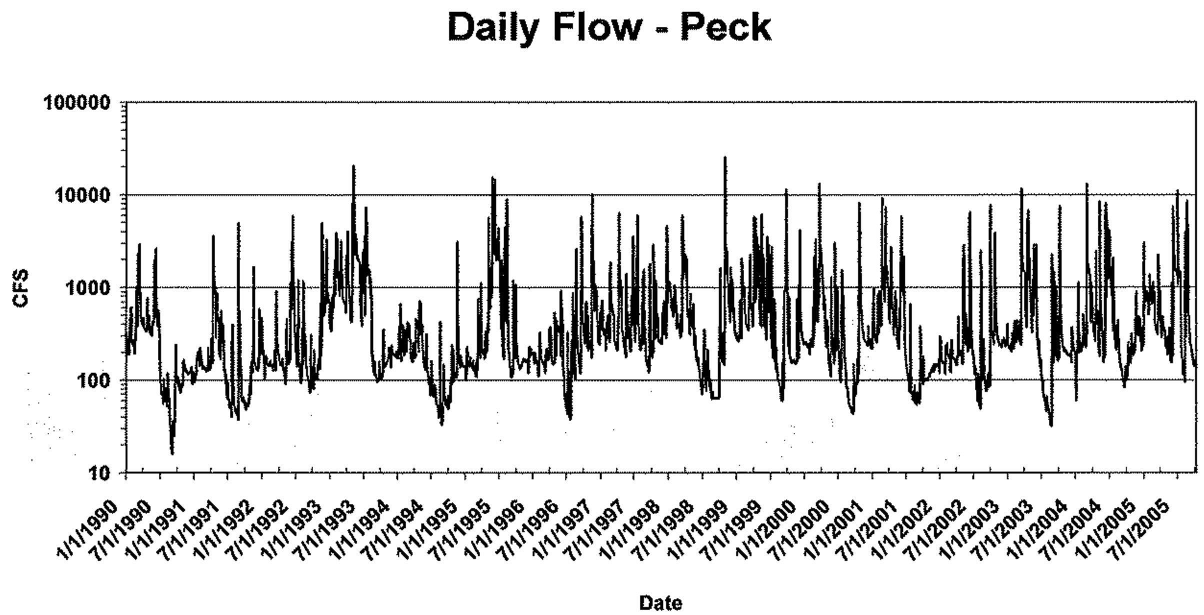
1. Kansas Ground Water, An Introduction to the State's Water Quantity, Quality, and Management Issues, compiled by Rex Buchanan and Robert W. Buddemeier. Kansas Geological Survey, Educational Series 10. 1993. http://www.kgs.ku.edu/Publications/Bulletins/ED10/index.html.

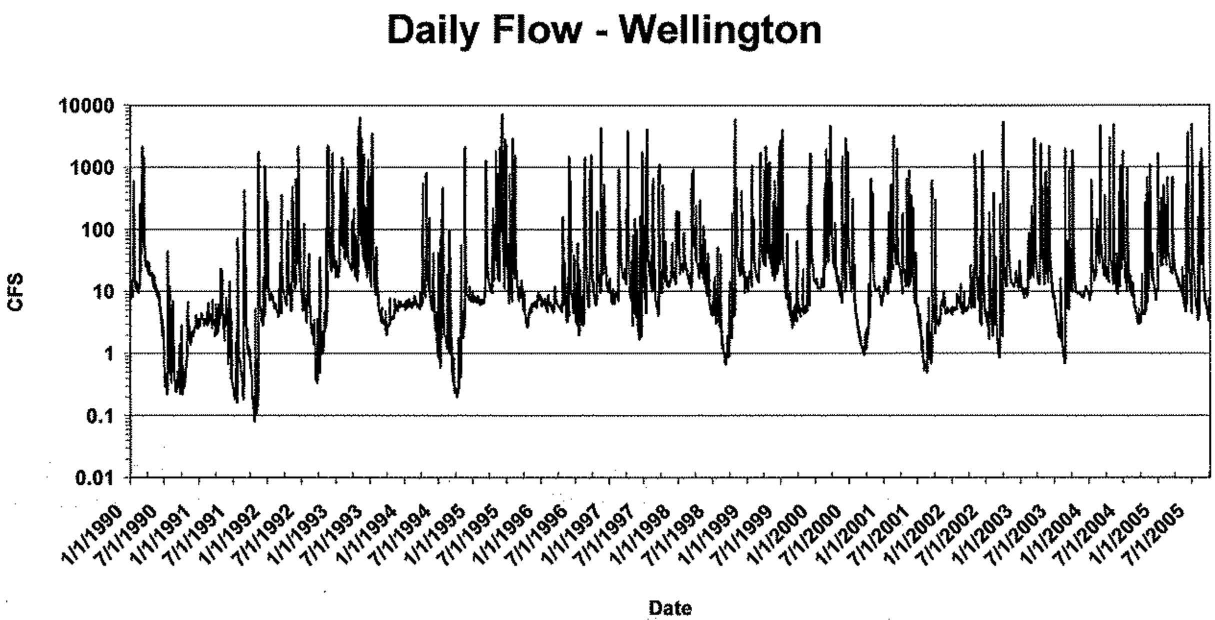
2. Geohydrology and Saline Ground-water Discharge to the South Fork Ninnescah River in Pratt and Kingman Counties, South-central Kansas. U.S. Geological Survey, Water-Resources Investigations Report 93-4177. 1993.

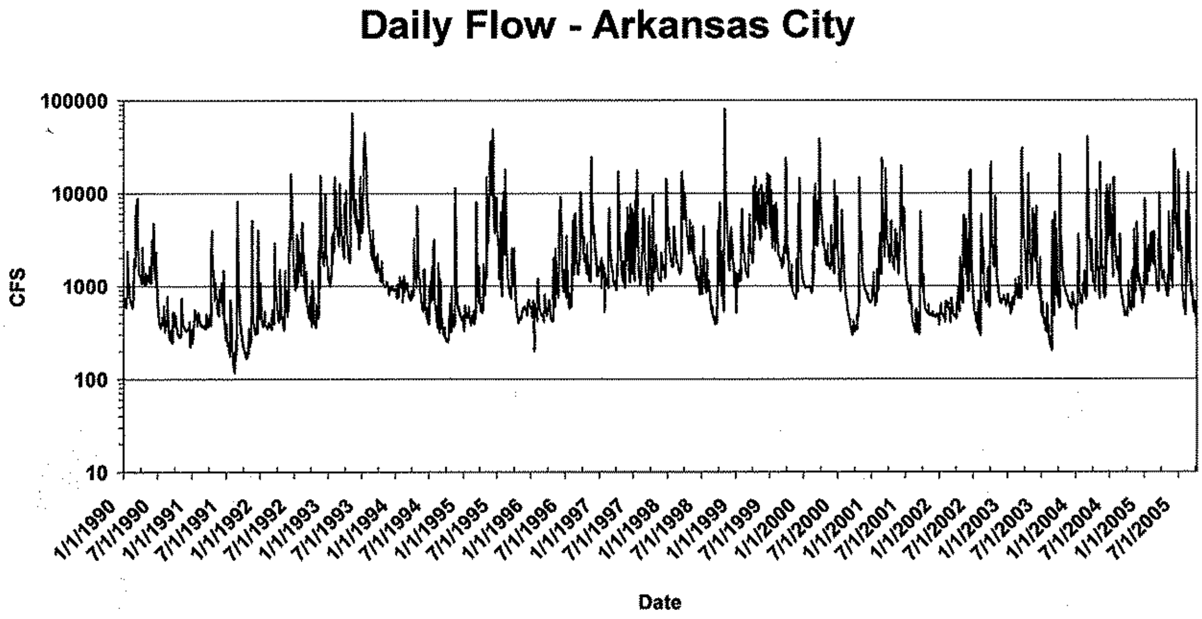
Appendix A. USGS Daily Flows Charts



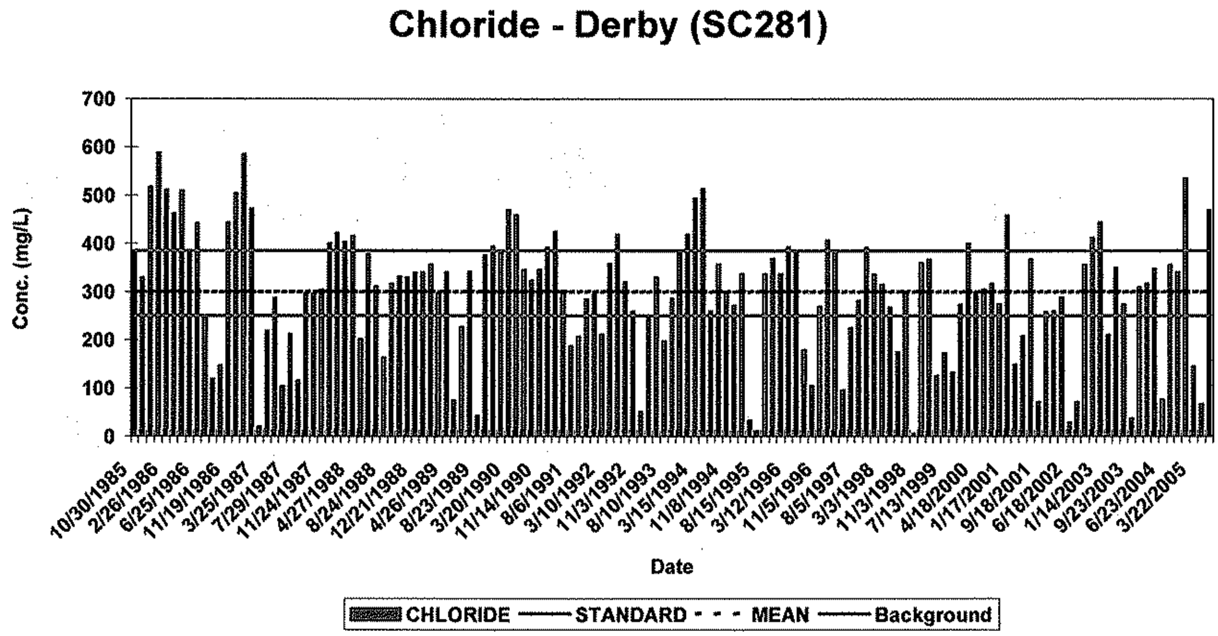


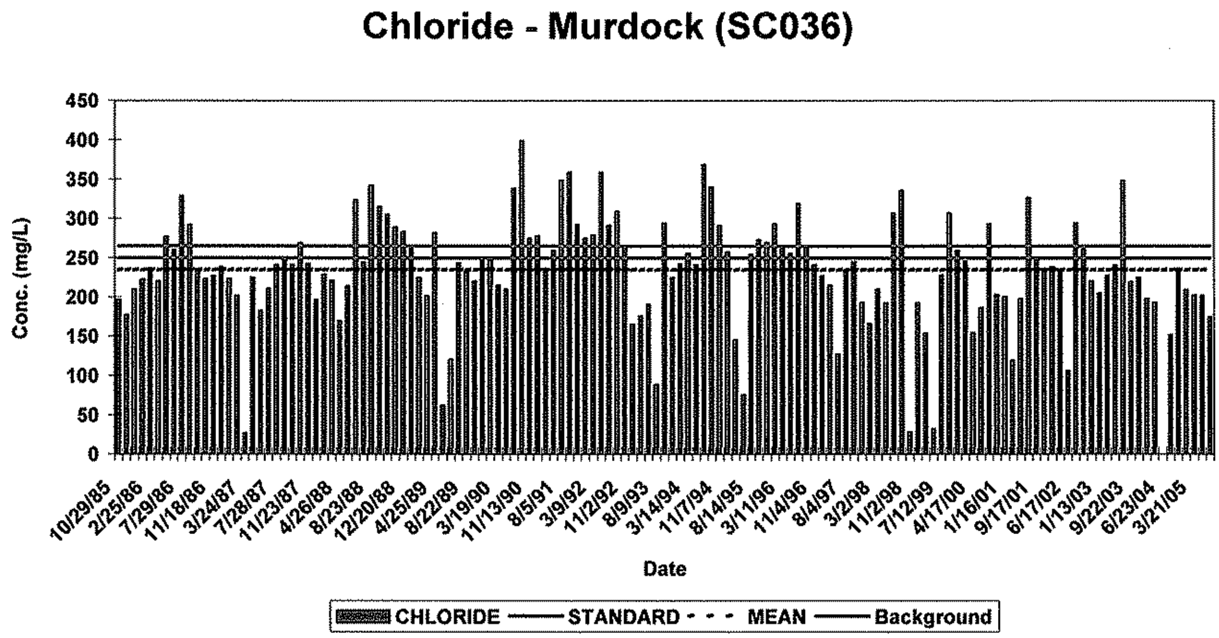

Daily Flow - Peck
100000
10000
1000
100
10
CFS
1/1/1990
7/1/1990
1/1/1991
7/1/1991
1/1/1992
7/1/1992
1/1/1993
7/1/1993
1/1/1994
7/1/1994
1/1/1995
7/1/1995
1/1/1996
7/1/1996
1/1/1997
7/1/1997
1/1/1998
7/1/1998
1/1/1999
7/1/1999
1/1/2000
7/1/2000
1/1/2001
7/1/2001
1/1/2002
7/1/2002
1/1/2003
7/1/2003
1/1/2004
7/1/2004
1/1/2005
7/1/2005
Date


Daily Flow - Wellington
10000
1000
100
10
1
0.1
0.01
CFS
1/1/1990
7/1/1990
1/1/1991
7/1/1991
1/1/1992
7/1/1992
1/1/1993
7/1/1993
1/1/1994
7/1/1994
1/1/1995
7/1/1995
1/1/1996
7/1/1996
1/1/1997
7/1/1997
1/1/1998
7/1/1998
1/1/1999
7/1/1999
1/1/2000
7/1/2000
1/1/2001
7/1/2001
1/1/2002
7/1/2002
1/1/2003
7/1/2003
1/1/2004
7/1/2004
1/1/2005
7/1/2005
Date

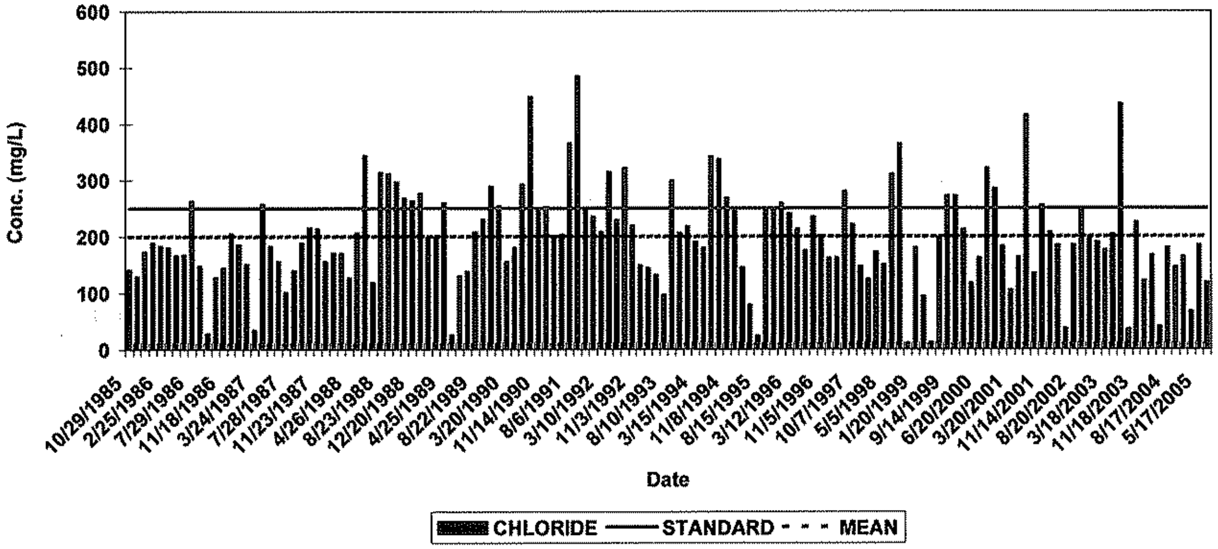

Daily Flow - Arkansas City
100000
10000
1000
100
10
CFS
1/1/1990
7/1/1990
1/1/1991
7/1/1991
1/1/1992
7/1/1992
1/1/1993
7/1/1993
1/1/1994
7/1/1994
1/1/1995
7/1/1995
1/1/1996
7/1/1996
1/1/1997
7/1/1997
1/1/1998
7/1/1998
1/1/1999
7/1/1999
1/1/2000
7/1/2000
1/1/2001
7/1/2001
1/1/2002
7/1/2002
1/1/2003
7/1/2003
1/1/2004
7/1/2004
1/1/2005
7/1/2005
Date

Appendix B. Charts of Chloride Concentrations over Time

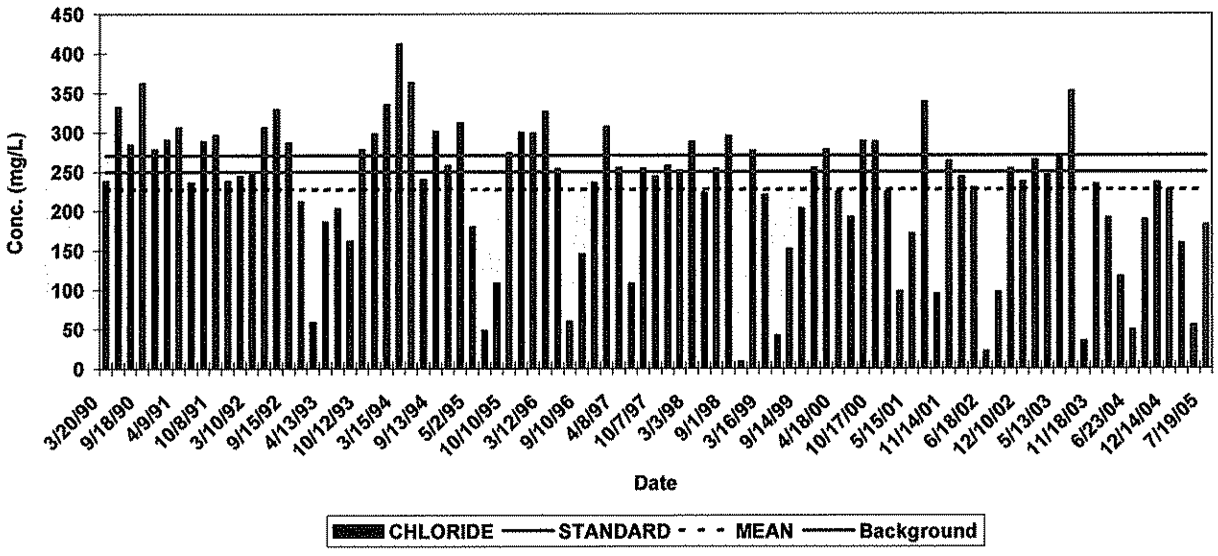




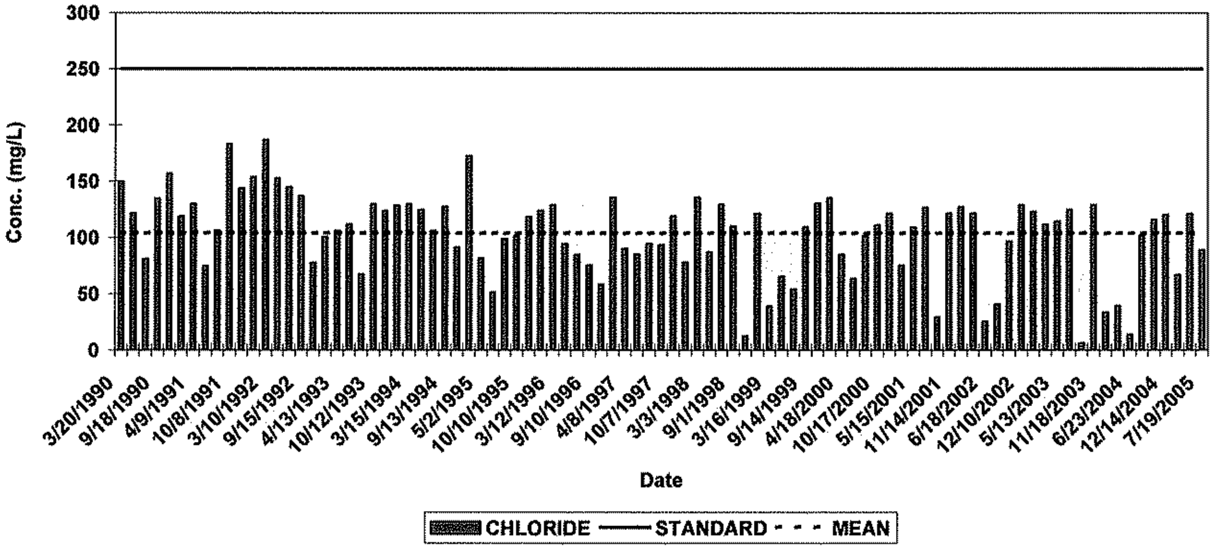
Chloride - Belle Plaine (SC280)



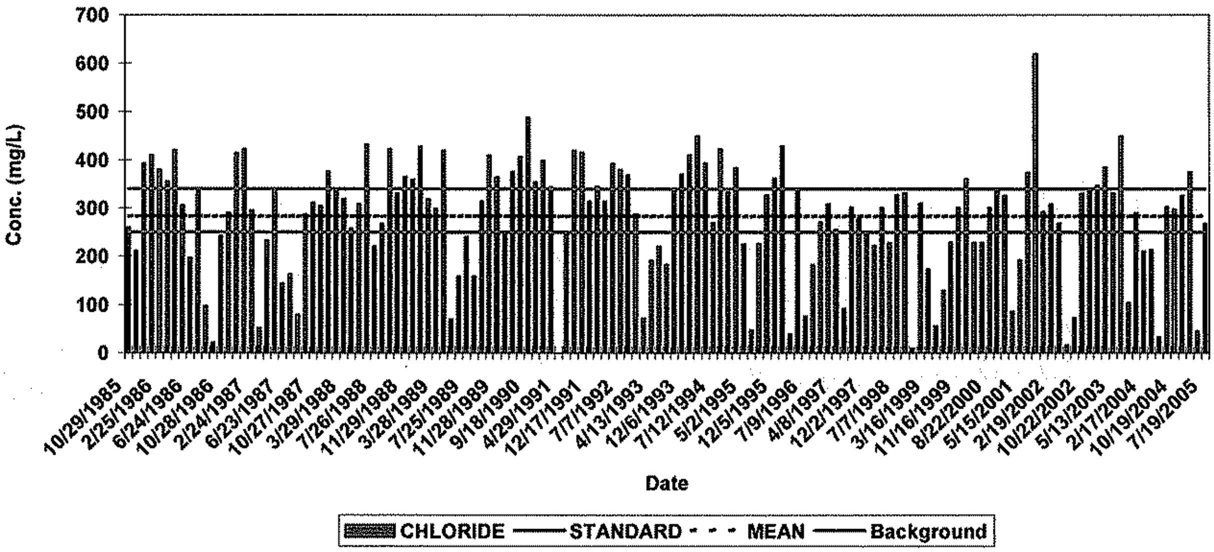
Chloride - Oxford (SC527)



Chloride - Wellington (SC528)

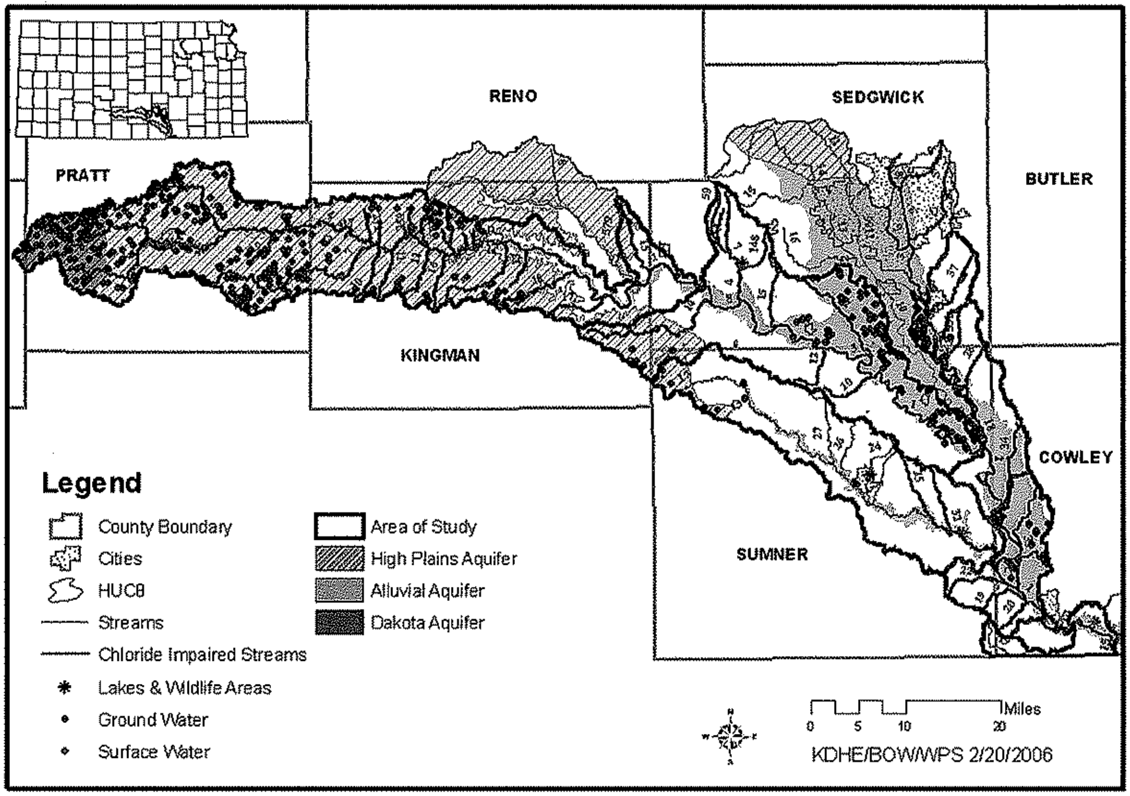


Chloride - Arkansas City (SC218)



Appendix C. Additional Maps

Irrigation Use - Points of Diversion and Aquifers



Appendix D. Load Allocation Calculation Spreadsheets

Baseflow (Dec 91)

Site	Flow %	Fac_Name	Ave Flow* (cfs)	Ave Conc (mg/L)	WLA (tons/day)	LA (tons/day)	WLA+LA (tons/day)	Dec 91 Conc. (mg/L)	Dec 91 Flow	Load (tons/day)
Derby (281)	96%							285	163	125.43
		Upstream Flow	163.00	285		125.43				
		City of Derby	2.58	449	3.13					
		Total	165.58	287.56			128.56			
		Pratt	1.13	*300*	0.92					
		Cunningham	0.09	*300*	0.07					
		KGS - Calista	0.02	*300*	0.01					
		Fabpro	0.07	133	0.03					
		Kingman	0.77	*300*	0.63					
		GW Seepage	*153*	*259*		*106.99*				
Murdock (036)	46%							259	155	108.39
		Total	155.09	259.47			108.65			
		Flow from SF Ninnescah	155.09	259.47			108.65			
		Garden Plain	0.14	119	0.04					
		Viola	0.02	*300*	0.02					
		Clearwater	0.26	*300*	0.21					
		Air Products	0.03	219	0.02					
		Belle Plaine	0.26	*300*	0.21					
		GW Seepage	*0*	*0*	0.00	0.00				
		Load Loss	*-18*	*310*		*-15.07*				
Peck (280)	74%							253	138	94.27
		Total	137.80	252.88			94.08			
		Flow from Derby	165.58	287.56			128.56			
		Flow from Peck	137.80	252.88			94.08			
		Mulvane	0.55	143	0.21					
		GW Seepage	*30*	*190*		*15.39*				
		Load Loss	*-71*	*360*		*-69.01*				
Oxford (527)	96%							238	263	169.00
		Total	262.92	238.39			169.23			
		Conway Springs	0.17	*300*	0.14					
		Wellington	1.30	122	0.43					
		Intervening Flow	*3.2*	*105*		*0.91*				
Wellington (528)	70%							117	4.7	1.48
		Total	4.68	116.96			1.48			
		Flow from Oxford	262.92	238.39			169.23			
		Upper Slate Flows	4.68	116.96			1.48			
		Lower Slate Flows	*0.7*	*40000*		*75.60*				
		Oxford	0.19	*300*	0.15					
		Geuda Springs	0.01	*300*	0.01					
		GW Seepage	*56*	*195*		*29.48*				
Ark City (218)	95%							314	325	275.54
		Total	324.50	314.96			275.95			
		Flow from Ark City	324.50	314.96			275.95			
Below SC218		Ark City	2.17	153.18	0.90					
		Total	326.67	313.89			276.85			

* Flow for point source is 2/3 of the design flow converted from MGD to CFS.

All Italic numbers are estimates.

Groundwater Remediation Projects

Site	Flow %	Fac_Name	Ave Flow* (cfs)	Ave Conc (mg/L)	WLA (tons/day)	LA (tons/day)	WLA+LA (tons/day)	Dec 91 Conc. (mg/L)	Dec 91 Flow	Load (tons/day)
Derby (281)	96%							285	**163**	125.43
		Upstream Flow	**163**	**285**		**125.43**				
		City of Derby	**2.58**	**449**	**3.13**					
		GW Remediation Project	**1.55**	**600**	**2.51**					
		Total	**167.13**	**290.45**			**131.07**			
		Pratt	**1.13**	***300***	**0.92**					
		Cunningham	**0.09**	***300***	**0.07**					
		KGS - Calista	**0.02**	***300***	**0.01**					
		Fabpro	**0.07**	**133**	**0.03**					
		Kingman	**0.77**	***300***	**0.63**					
		GW Seepage	***153***	***259***		***106.99***				
		GW Remediation Project	**1.55**	**600**	**2.51**					
Murdock (036)	46%							259	**155**	108.39
		Total	**156.64**	**262.84**			**111.16**			
		Flow from SF Ninnescah	**156.64**	**262.84**			**111.16**			
		Garden Plain	**0.14**	**119**	**0.04**					
		Viola	**0.02**	***300***	**0.02**					
		Clearwater	**0.26**	***300***	**0.21**					
		Air Products	**0.03**	**219**	**0.02**					
		Belle Plaine	**0.26**	***300***	**0.21**					
		GW Seepage	***0***	***0***	**0.00**	**0.00**				
		Load Loss	***-18***	***310***		***-15.07***				
		GW Remediation Project	**1.55**	**600**	**2.51**					
Peck (280)	74%							253	**138**	94.27
		Total	140.90	260.52			99.11			
		Flow from Derby	**167.13**	**290.45**			**131.07**			
		Flow from Peck	140.90	260.52			99.11			
		Mulvane	**0.55**	**143**	**0.21**					
		GW Seepage	***30***	***190***		***15.39***				
		Load Loss	***-71***	***360***		***-69.01***				
		GW Remediation Project	**1.55**	**600**	**2.51**					
Oxford (527)	96%							238	**263**	169.00
		Total	**269.12**	**246.72**			**179.27**			
		Conway Springs	**0.17**	***300***	**0.14**					
		Wellington	**1.30**	**122**	**0.43**					
		Intervening Flow	***3.2***	***105***		***0.91***				
		GW Remediation Project	**1.55**	**600**	**2.51**					
Wellington (528)	70%							117	**4.7**	1.48
		Total	**6.23**	**237.23**			**3.99**			
		Flow from Oxford	**269.12**	**246.72**			**179.27**			
		Upper Slate Flows	**6.23**	**237.23**			**3.99**			
		Lower Slate Flows	***0.7***	***40000***		***75.60***				
		Oxford	**0.19**	***300***	**0.15**					
		Geuda Springs	**0.01**	***300***	**0.01**					
		GW Seepage	***56***	***195***		***29.48***				
		GW Remediation Project	**1.55**	**600**	**2.51**					
Ark City (218)	95%							314	**325**	275.54
		Total	333.80	322.90			291.02			
		Flow from Ark City	333.80	322.90			291.02			
Below Ark City		**Ark City**	**2.17**	**153.18**	**0.90**					
		Total	**335.97**	**321.81**			**291.92**			

* Flow for point source is 2/3 of the design flow converted from MGD to CFS.

All Italic numbers are estimates.

May 92 Condition

Site	Flow %	Fac_Name	Ave Flow* (cfs)	Ave Conc (mg/L)	WLA (tons/day)	LA (tons/day)	WLA+LA (tons/day)	May 92 Conc. (mg/L)	May 92 Flow	Load (tons/day)
Derby (281)	94%							358	**174**	168.19
		Upstream Flow	**174.00**	**358**		**168.19**				
		City of Derby	**2.58**	**449**	**3.13**					
		Total	**176.58**	**359.33**			**171.32**			
		Pratt	**1.13**	***300***	**0.92**					
		Cunningham	**0.09**	***300***	**0.07**					
		KGS - Calista	**0.02**	***300***	**0.01**					
		Fabpro	**0.07**	**133**	**0.03**					
		Kingman	**0.77**	***300***	**0.63**					
		GW Seepage	***100***	***360***		***97.20***				
Murdock (036)	78%							359	**102**	98.87
		Total	102.09	358.65			98.86			
		Flow from SF Ninnescah	**102.09**	**358.65**			**98.86**			
		Garden Plain	**0.14**	**119**	**0.04**					
		Viola	**0.02**	***300***	**0.02**					
		Clearwater	**0.26**	***300***	**0.21**					
		Air Products	**0.03**	**219**	**0.02**					
		Belle Plaine	**0.26**	***300***	**0.21**					
		GW Seepage	***19***	***120***		**6.16**				
		Load Loss	***-16***	***360***		***-15.55***				
Peck (280)	84%							315	**106**	90.15
		Total	105.80	314.94			89.96			
		Flow from Derby	**176.58**	**359.33**			**171.32**			
		Flow from Peck	105.80	314.94			89.96			
		Mulvane	**0.55**	**143**	**0.21**					
		GW Seepage	***60***	***190***		***30.78***				
		Load Loss	***-59***	***360***		***-57.35***				
Oxford (527)	94%							306	**284**	234.64
		Total	**283.92**	**306.45**			**234.92**			
		Conway Springs	**0.17**	***300***	**0.14**					
		Wellington	**1.30**	**122**	**0.43**					
		Intervening Flow	***4.5***	***157***		***1.91***				
Wellington (528)	63%							153	**6**	2.48
		Total	**5.98**	**153.52**			**2.48**			
		Flow from Oxford	**283.92**	**306.45**			**234.92**			
		Upper Slate Flows	**5.98**	**153.52**			**2.48**			
		Lower Slate Flows	***1***	***40000***		***108.00***				
		Oxford	**0.19**	***300***	**0.15**					
		Geuda Springs	**0.01**	***300***	**0.01**					
		GW Seepage	***71***	***195***		***37.38***				
Ark City (218)	92%							392	**362**	383.14
		Total	362.10	391.69			382.94			
		Flow from Ark City	362.10	391.69			382.94			
Below SC218		**Ark City**	**2.17**	**153.18**	**0.90**					
		Total	**364.27**	**390.27**			**383.84**			

* Flow for point source is 2/3 of the design flow converted from MGD to CFS.
All Italic numbers are estimates.